Instruments

THE MAGAZINE OF Measurement and Control

Vol. 11
MARCH
1938
No. 3

Engin. Library
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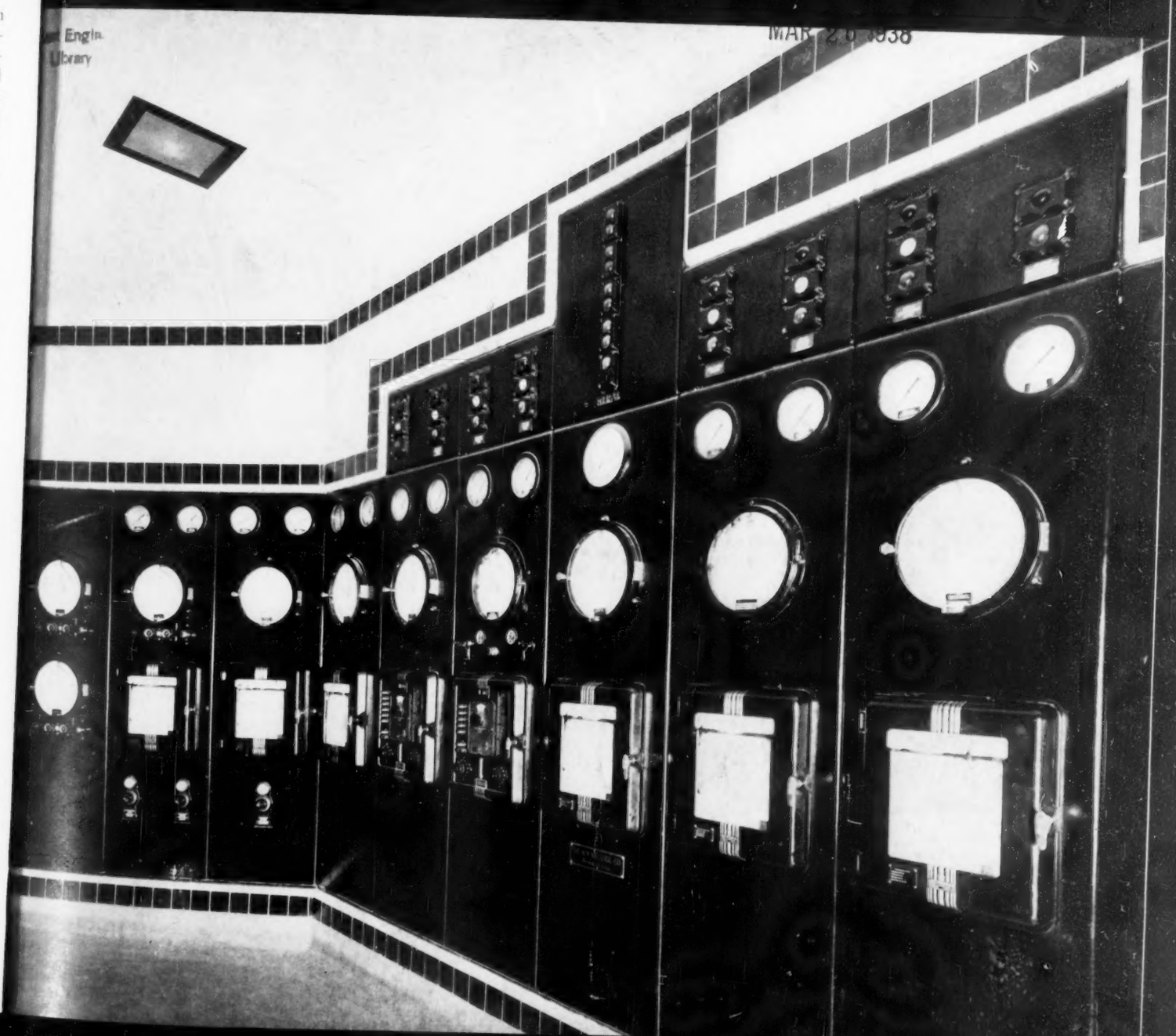


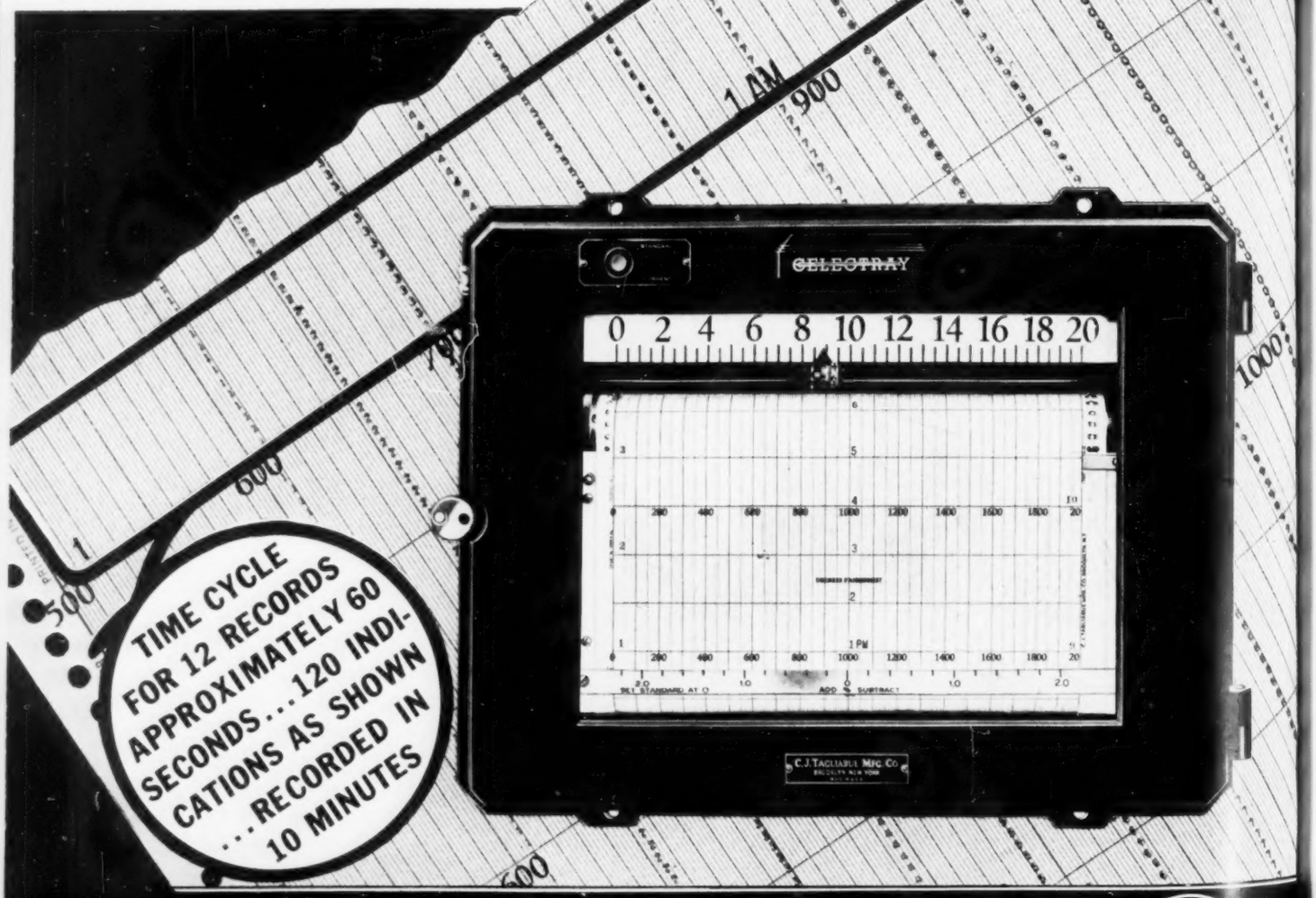
SUPER SPEED takes the BLIND SPOTS out of temperature records

TAG's Super Speed CELECTRAY Recorder has dramatically exposed heretofore uncharted, but vital, temperature changes in many industrial processes involving continuous or batch production. Conventional recorders of long cyclic time fail to measure sudden temperature changes caused by chemical reactions. But, the Super Speed CELECTRAY Multiple Recorder takes these blind spots out of temperature records, even though changes may be taking place as rapidly as 200° per minute!

Formerly, it has been necessary, in order to record a considerable number of points, to use several instruments, even though they be multiple recorders. Now, the Super Speed CELECTRAY puts ALL these records on ONE chart . . . a complete cycle of 12 records in 60 to 70 seconds with incomparable accuracy . . . recording 120 temperature indications as shown in 10 minutes.

Translate this super speed, supreme accuracy and operating facility into terms of processing economy and product uniformity, and you'll want to know the whole absorbing story of these competent instruments. They employ the CELECTRAY principle of an inertialess beam of light reflected from a mirror galvanometer, which, in moving on and off a phototube, passes the "controlling edge" of a screen.

Ask about it!



TIME CYCLE FOR 12 RECORDS APPROXIMATELY 60 SECONDS . . . 120 INDICATIONS AS SHOWN . . . RECORDED IN 10 MINUTES

C. J. TAGLIABUE MFG. CO.

Park & Nostrand Ave's., Brooklyn, N. Y.

TAGLIABUE BROOKLYN N.Y.

65% OF ALL TEMPERATURE CONTROL

. . . as simple as regulating your bath

When your bath cools you *open* the hot water . . . let it run . . . then *shut* it off. At least 65% of all temperature control problems in industry are just as simple—a fortunate whim of Mother Nature. Most temperature control jobs have large heat capacity—like the bath tub. A simple Foxboro "Open and Shut" Controller is the best for all such applications . . . for dryers, kettles, kilns, ovens, cookers, etc.

For a quarter of a century Foxboro has solved 65% of all types of temperature control problems with the "Open and Shut" type of control. Millions of chart records have written the verdict: The simplest is best.

If you are interested in results and would like to save money have a Foxboro Engineer survey your needs. Write for complete information. The Foxboro Company, 46 Neponset Avenue, Foxboro, Mass., U. S. A. Branch Offices in 25 Principal Cities.

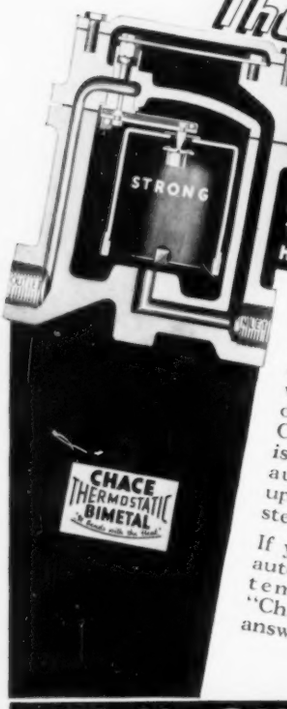
35% of control problems cannot be handled by "Open and Shut" Control. To satisfy specific problems involving varying amounts of throttling range Foxboro perfected the Stabilog Controller. It does a perfect job on the 35%. Each type of Foxboro Controller has its definite place. Foxboro Engineers will gladly help you.

FOXBORO

REG. U. S. PAT. OFF.

Certified TEMPERATURE CONTROLLERS

"We Use CHACE Thermostatic BIMETAL IN THE STRONG STEAM TRAPS"
THE STRONG, CARLISLE AND HAMMOND CO. CLEVELAND, OHIO.



THIS trap is recommended for removing condensation from unit heaters, jacketed cookers and similar units where very rapid elimination of air is required in starting. Chace Thermostatic Bimetal is the active element used to automatically operate the upper valve in these Strong steam traps.

If your product calls for an automatic action at a given temperature, perhaps "Chace" is your one best answer.

W. M. CHACE CO.
1609 Beard Avenue - - - Detroit Mich.

ECONOMIZE WITH POWERS
THERMOMETER-REGULATORS
Controls Heating or Cooling Mediums

TWO INSTRUMENTS IN ONE—Combining a temperature regulator with an indicating thermometer gives a visual check on the performance of the regulator and makes it easy to adjust it for the required operating temperature.

EASY TO INSTALL—Both thermometer and regulator operate from the same thermal system. Write for Bulletin No. 229.

AIR OPERATED REGULATORS WITH THERMOMETERS—Our complete line of compressed air operated regulators combined with indicating and recording thermometers are described in Bulletin 226.

THE POWERS REGULATOR CO., 2734 Greenview Avenue, CHICAGO—231 E. 46th Street, NEW YORK—Offices in 45 Cities. See your phone book.

45 Years POWERS
of Automatic Temperature and Humidity Control

Instruments
THE MAGAZINE OF MEASUREMENT and CONTROL

VOL. 11 No. 3

MARCH, 1938

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Courtesy Leeds & Northrup Co.

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Published Monthly on the 15th by
THE INSTRUMENTS PUBLISHING COMPANY
1117 Wolfendale Street, Pittsburgh, Pa.

RICHARD RIMBACH, Managing Editor
M. F. BEHAR, Editor

BRANCH OFFICES

Boston: James Condon, 6 Marlboro St. (Kenmore 2354)
New York: R. K. Farnham, 118 E. 28th St. (Lexington 2-4637)
Chicago: William Farnham, 201 N. Wells St. (Andover 4180)
Cincinnati: E. Eggers, 2316 Kenilworth Ave. (Jefferson 4722)
Philadelphia: R. K. Farnham, 1533 Cherry St. (Rittenhouse 2530)

Annual Subscription: U. S. $2.00. All other countries $3.00 *payable in advance* (remit by New York draft). Copyright 1938 by The Instruments Publishing Company. Entered as second-class matter January 6, 1932, at the post office at Pittsburgh under the Act of March 3, 1879.

INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

IN THIS ISSUE

Seldom have we printed a two-page feature containing so much "practical dope" as Batcher's check-lists of cathode-ray oscillograph applications. (Pages 88-89.)

Owing to the interest that was shown in Dr. Eddy's article on temperature and heating-rate control in our July 1935 issue, we feel certain that the article by his associate R. J. Smith will be welcome. (Pages 90-92.)

In response to requests indicating a widespread demand, we shall print several articles on the latest calibration methods. Egnor's (pages 93-95) will be followed by one from another company in a month or two, and later by others also promised to us.

With his rare knack for fascinatingly presenting technical subjects, Dr. Williams begins this month a new series on Penetration Hardness Methods. (Pages 96-99.)

THE FRONT COVER

shows another of those beautiful tile-enshrined control boards, by which the Atlantic Refining Co. proclaims its appreciation of modern Instrumentation. Leeds & Northrup "Micromax" potentiometers are easily recognizable. The round-chart instruments are Brown and Foxboro. The Kellogg Co. were the consulting engineers.

NOTICE

"ROTAMETERS"

Fig. 18 on page 24 of the January 1938 issue should have been credited to *Schuette & Koerting Co.*, Philadelphia, Pa.

This company has *not* discontinued the manufacture of Rotameters and informs us that "as a matter of fact our sale of these instruments is increasing rapidly."

It wasn't author Pigott's fault but ours.

CRIMES AGAINST PROGRESS

IN the first paragraph of his annual progress report* as Director of the Biochemical Research Foundation of the Franklin Institute, Dr. Ellice McDonald says:

"We take this opportunity of laying before you . . . what we will be doing in the near future . . . an example to other laboratories to offer their programs so that there can be none of THAT CRIME AGAINST RESEARCH—DUPLICATION." [Capitals ours.]

Congratulations to Dr. McDonald for summarizing in five words an important plank in *Instruments'* platform—a policy we have set forth in fifty (or perhaps five hundred) words.

Needless duplication is not only a crime against research: it is a crime against industry, against progress.

Moreover, we are impelled to elaborate on Dr. McDonald's epigram, by declaring that another crime against engineering progress is RETARDATION. When an improved method has been discovered and has reached the stage of practical embodiment, it is a crime to retard its adoption in any field of application where it would reduce the sum total of human drudgery.

To prevent such crimes is the part of good citizenship. *Instruments* does its part. Several features of this magazine are designed to prevent needless duplications. The entire magazine serves to prevent needless retardation.

Every noteworthy act of good citizenship is opposed by "the forces of reaction," by organized crime, by crime-profiting politicians, etc. We take pride in being opposed by certain influences. . . .

Every noteworthy act of good citizenship is criticized by well-meaning reformers who don't always see the value of other schemes than their own. An old subscriber (who is a genius in his own field) criticizes us for including the "Instrumentation Forum" as a regular feature in every issue:

"I suspect that certain companies exploit your Forum as a cheap consulting engineering service. . . . Let such companies pay for consulting services what they are worth. . . ."

Extract from our reply:

"Of the fifteen problems which have been published so far, thirteen came from large companies or institutions which do their full duty in supporting research—companies like General Motors, duPont, etc., and government departments which employ a number of scientists. When a firm (large or small) tells us of a problem which we believe requires consulting service, we do not print their problem but simply refer them to consulting engineering firms, laboratories or individual consultants—including you. In one recent case, we practically told the inquiring firm that they should hire a physicist. We never charged a penny for printing a problem. The $5 prizes are paid by *Instruments* alone."

Civilization is being enriched by industrial firms maintaining research departments, spending millons of dollars a year for salaries. If many research men wasted time in needless duplication, stockholders would compel reducing research budgets. Our Forum promotes the employment of *more* research men in the long run—for exactly the same basic reasons that the labor-saving measurement and control devices we report in our columns create new jobs in the long run—if their adoption is not criminally retarded.

*Presented Dec. 5, 1937. Printed in the Feb. 1938 *Journal of the Franklin Institute*, pages 121-169.

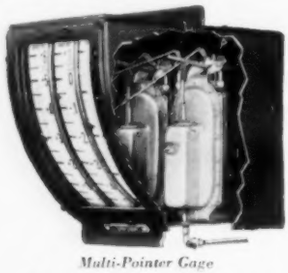
BAILEY METERS

METERS and CONTROL *for Boiler Room Service . . .*

Boiler Meters Indicate, record and integrate Steam Flow from the boiler, record Air Flow supplied for combustion and record Flue Gas Temperature. The use of this meter reduces fuel cost, lessens maintenance and outage, lowers standby costs, and adds capacity.

Bailey Boiler Meter

Multi-Pointer Gages for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



Multi-Pointer Gage

Flow Meters. For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

Coal Meter

Granular Material Meters For accurately measuring the flow of coal or other granular materials in gravity chutes from overhead bunkers. The total quantity of granular material is shown on a large illuminated counter which may be easily read at a distance of 50 feet.

Control Systems. Make possible the everyday operation of equipment for steam generation and utilization at test efficiencies. They are applied to the control of combustion, feed water, superheat, desuperheat and other factors.

Complete Information on any of the above Bailey products will be gladly furnished upon request.

G-7

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

NEW INSTRUMENTS

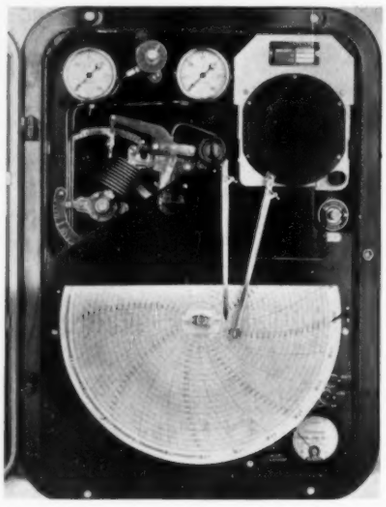
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Air-operated Control Potentiometer

Three of the maker's developments are combined into "Pneumatic Reset Potentiometer Controller." (1) Measuring system is "Pyromaster" (see *Instruments*, April 1937, page 97 for general description; July 1937, page 172 for technical details) and is available with thermocouple or resistance-thermometer primary elements. (2) Pneumatic-relay system is "Free Vane" (see *Instruments*, Jan. 1932, page 9; August 1936, page 213; Sept. 1936, page 248). (3) Automatic-reset feature recently introduced (see *Instruments*, February 1938, page 57). By means of upper knob, visible on illustration between the air-supply gage and the controlled-air-line gage, the speed of reset may be adjusted; by means of lever at left, throttling range may be adjusted; by means of knob at right, hand or automatic control may be selected. Other adjustments, too, are accessible.—*The Bristol Co., Waterbury, Conn.*



Fluorescent Chalk

A newly-developed fluorescent chalk appears and marks like ordinary chalk under normal light. It glows in the dark with a strong green light when irradiated with ultraviolet rays. An obvious use, therefore, is jotting down memoranda during the course of a fluoroscopic examination, when a u-v. source is handy. New material aids also lecturers who, while showing projected pictures, wish to display visible written messages, especially during the showing of moving pictures with sound.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

Photocell

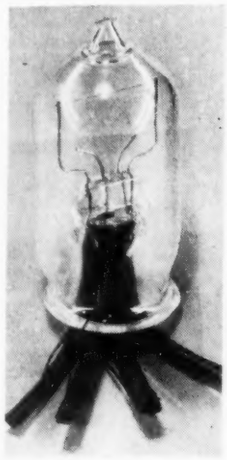
A dry-disk self-generating photocell of the blocking-layer type is announced. Its one-piece molded Bakelite housing is provided either with prongs to fit radio tube socket, or with binding posts. The self-generating cell proper is an "Electrocell" element with an active surface of $1\frac{1}{2}$" diam. having a sensitivity of about six microamperes per footcandle. These elements are said to be permanently stable (continuous exposure to direct sunlight for nine months is said to cause negligible loss in output), to have the highest spectrum efficiency obtainable, and to be rugged enough to make special care in handling unnecessary.—*The Hickok Electrical Instrument Co., Cleveland, Ohio.*

Optical Protractor

An example of optical principles applied to practical production methods, this new instrument is used for measuring and checking the exact angular relation between surfaces, edges and holes. The "B&L Optical Protractor" does the same work as the sine bar, with the advantage, it is said, that direct reading replaces a combination of mensuration and calculation. No mathematical facility is required on the part of the operator.

Angles to one minute of arc can be read directly off scale. Protractor is self-contained, requires no accessory apparatus in use, can be used for setting up work on jigs, boring, milling, drilling, grinding, planing and shaping machines, is useful for determining tapers, dovetails, grooves and all sloping or angular surfaces. For using the instrument upon round stock, the slotted V base with a secondary level is provided. Scale and vernier are completely housed in a metal casing into which is also mounted the level vial, correct to one minute of arc.—*Bausch & Lomb Optical Co., Rochester, N. Y.*

Vacuum . . . Thermocouples



Ranges from 1 milliampere to 10 amperes, in either contact or separate heater types. Prices from $3.00, quantity discounts.

Write for Bulletin "A"

AMERICAN Electrical Sales Co. Inc.
67 E. 8th St. New York, N. Y.

S-M-O-O-T-H VOLTAGE CONTROL for A.C. circuits

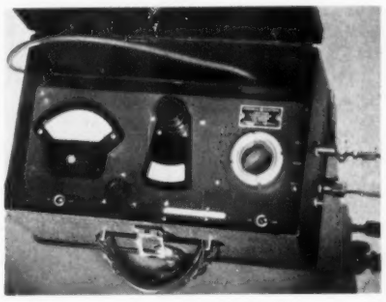
The Type "TH" Transtat is the new continuously variable auto-transformer regulator . . . the ideal voltage control for a.c. circuits. It offers high efficiency, good regulation, great flexibility and dependable construction at moderate cost. Standard types are available for controlling voltage to single-phase and polyphase loads rated 10 Kva. and smaller, 50 or 60 cycles, 115, 230 or 460 volts. May we send you bulletin 51-1 which contains complete data?

TRANSTAT
VOLTAGE REGULATORS

AMERICAN TRANSFORMER CO.
178 Emmet St. Newark, N. J.

Furnace Atmosphere Humidity Meter

Developed for determining moisture content of atmosphere in industrial heat-treating furnaces, but obviously suitable for other applications, a new type of



dew-point apparatus, known as the Dew-point Potentiometer, consists of a polished metal mirror located in a small chamber opposite a sight glass; means for cooling the mirror and heating it when necessary; and means for reading its temperature. Gas to be tested is passed continuously through the chamber. In normal use the temperature of the mirror is lowered by directing against its back a jet of cooling gas from a storage tank, through an expansion nozzle lined up with its center. A spot of dew appears when the dew-point temperature of the gas is reached. A miniature lamp serves as the heat source when measuring high dew-point temperatures. Formation of dew at center of mirror is definite, hence easily observed. A fine-wire thermocouple at the back of the mirror; a balancing circuit with direct-reading millivoltmeter; a thermometer for reference-junction temperature; and a compensator for reference-junction adjustment, constitute the means for obtaining the mirror temperature at the instant that the dew appears. This enables conversion to the weight of water vapor per cubic foot of gas, or other convenient unit. Range of dew-point temperatures is from —40° F. to +130° F.—*General Electric Co., Schenectady, N. Y.*

Neutral Wedge Photometer

"Aminco" neutral wedge photometer is for precise determination of micro and macro quantities of lead, fluorine, arsenic, organic spray residues, for determining extent of damage to wool fibers, for many other substances and for practically all clinical determinations using color reactions. Quantities as small as 10^{-8} grams are said to be accurately measured. With a complete set of color filters covering entire visible spectrum in small steps of narrow bands, together with data that can be supplied by manufacturer for a particular instrument for converting scale readings into percent transmission or density units, useful abridged spectrophotometric curves can be obtained for any colored solution.—*American Instrument Co., 8010 Georgia Ave., Silver Springs, Md.*

NOW..

A BRAND NEW RCA AC OSCILLATOR AT LOWEST PRICE EVER

Stock No. 153, complete with RCA Metal Tubes

ONLY **$29.95**

HERE'S a new instrument at a sensationally low price! A typical RCA value, it offers a sparkling array of fine features. They include a giant 6½" direct reading 6 band dial with a spread of over 50"... one-volt output ... RCA Metal Tubes ... and many others.

This splendid new instrument comes in a snap-handle case with attractive blue-gray wrinkle finish. Write to us or see a local RCA Parts Distributor for full details—you'll be amazed that so much quality, so much value can be offered at so little cost!

• • •

RCA presents the "Magic Key" every Sunday, 2 to 3 P.M., E.S.T., on the NBC Blue Network.

Over three hundred million RCA radio tubes have been purchased by radio users ... In tubes, as in parts and test equipment, it pays to go RCA ALL THE WAY.

Ask your distributor or send 10c to Camden for a commemorative advertisement on RCA's television tube announcement.

RCA **Test Equipment**

RCA Manufacturing Co., Inc., Camden, N. J.
A Service of the Radio Corporation of America

One-ohm Standards

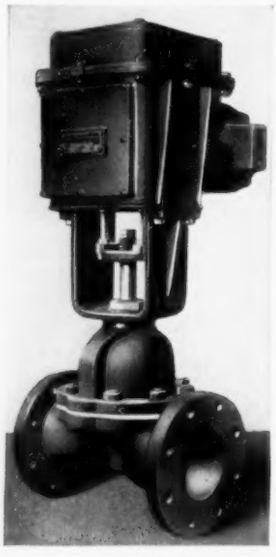
These one-ohm resistors represent an L&N modification of the Thomas type standards developed at the National Bureau of Standards. Even during the first few months after manufacture, maker reports, they have been found to be more stable than well-aged resistance standards of other types. These standards are adjusted in terms of the Absolute Ohm which will become effective as of January 1, 1940. In accordance with a preliminary announcement of the International Committee on Weights and Measures, this unit is taken as having the following relation to the present International Ohm:

1 Int. Ohm = 1.00048 Abs. Ohms.

Certificates may be obtained from the National Bureau of Standards, giving the value of a particular standard to one part in a million, in terms of the ohm as maintained by the Bureau.—*Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.*

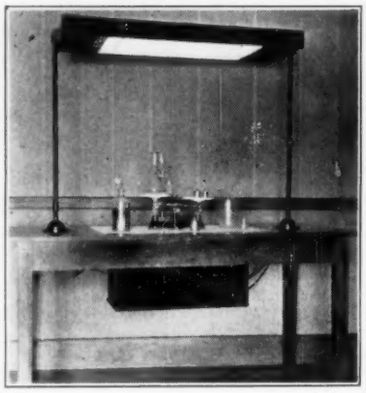
Valve Operator

A second and much larger unit, "Model C," added to "Type I" line of motor valve mechanisms, is designed to operate slip stem valves for heavier pressures



and in the larger sizes. The mechanism illustrated exerts an opening and closing force on the valve stem of 2000 lbs. with 5" per minute movement and 2½" stroke. Strokes up to 10" and speeds of 3" to 10" per minute are available, with corresponding changes in power. A novel power release feature positions the valve at definite open and closed points regardless of variable motor drift. This mechanism can be used either for full open and closed operation or for "throttling" control.—*Automatic Temperature Control Co., Inc., 34 East Logan St., Philadelphia, Pa.*

Barkon **COLOR MATCHING LAMPS**



Barkon Carbon Dioxide Lamps provide a technically accurate artificial daylight—do not change with age—a standard light source.

Write for Literature

BARKON-FRINK Tube Lighting Corp.

Long Island City New York

"MEGGER"

TRADE MARK REGISTERED U.S. PAT. OFF.

CAPACITANCE METER

Measures Electrostatic Capacity *Anywhere*

A new instrument—self-contained, with hand-generator source of test current . . . always ready for use, *anywhere*. Reads directly (like a voltmeter), compensates automatically for parallel (in-phase) resistance leakage.

Designed primarily for locating open-circuit faults in power cables, this new instrument is finding a variety of miscellaneous uses in shop, laboratory and field for capacitance measurements of cables, condensers and machines. As simple to use and as rugged as a "Megger" Insulation Tester. Ranges up to 10 microfarads, reading as low as .01 microfarad.

A shop type instrument, without automatic compensation, reads to as low as .00002 microfarad on a scale 12 inches long and using 60 cycles supply.

Write for Bulletin 1405-I

JAMES G. BIDDLE CO.

ELECTRICAL INSTRUMENTS

1211-13 Arch Street Philadelphia, Pa.

Dual-range "Clip-On" Ammeters

Three new models of the "Clip-On" ammeter, an instrument combining a hinged-core current transformer and a 2½" milliammeter (see *Instruments*, Feb. 1932, page 54; Oct. 1933, page 193; Jan. 1937, page 6) are announced, each a double-range ammeter: "Type H" 0-7.5/75 amps; "Type I" 0-25/150 amps, and "Type X" 0-300/3000 amps. There are now ten standard dual-range models, of which types "H" and "X" represent the extremes. Special models can be supplied with various combinations of full scales from 7.5 to 5000 amps.—*Ferranti Electric, Inc., 30 Rockefeller Plaza, New York City.*

Thermal Analysis Equipment

"Rockwell Thermal Analizer" is a direct-reading and autographic dilatometer consisting essentially of a 3" × 12" electric furnace, fixed and movable quartz tubes for positioning specimen and transmitting its dimensional changes, a 4" dial indicator with a scale range of 0.007" graduated in 0.00007", a round-chart recorder with corresponding scale and 3-hr. rotation period, rheostatic control, and provisions for either automatic constant-temperature control or automatic temperature-time-program control. In addition to model illustrated, others are available, including one so designed that entire dilatometer assembly (still holding

sample) may be rapidly removed from floor stand and furnace to quench sample and obtain uninterrupted heating and quenching curve. After initial calibration to obtain constants of quartz support and feeler (procedure said to be simple), all unknowns affecting determinations of expansion coefficients are said to be eliminated. "Analizer" records are said to show unmistakably all transformations and criticals in ferrous metallurgy and to permit also a wide variety of other investigations.—*The Stanley P. Rockwell Co. Inc., 296 Homestead Ave., Hartford, Conn.*

Accuracy in Metering

Cochrane

Cochrane
Feed Water Meters
and Recorders on Boiler
Instrument and Control Panel.

Accurate metering of fluid flow and definite knowledge of exact conditions prevailing at all times are essential for maintaining high efficiencies in steam generating equipment. Complete instrument and control apparatus protects plant investment and reduces operating costs.

The boiler panel illustrated above serves two 120,000 Lb/Hr boiler units and includes a Cochrane Flow Meter which accurately measures the feed water input to each boiler, and a Cochrane Liquid Level Meter which provides dependable continuous records of the boiler drum level of each unit.

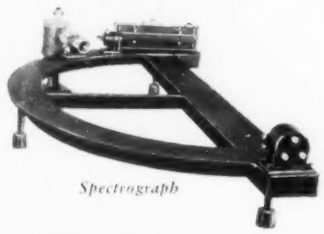
Thus, with these meters and the other associated instruments, an accurate accounting of conditions and rates of flow operations can be secured — permitting inefficient operations to be corrected and savings effected.

The extreme accuracy of Cochrane Meters makes them preferred by leading industrials.

Write for Publication 2096 giving details.

COCHRANE CORPORATION
3120 N. 17th St. Philadelphia, Pa.

SPECTROGRAPHIC EQUIPMENT



Spectrograph

A complete line of spectrographic equipment including Spectrograph, Comparator and Micro-Densitometer. For qualitative and quantitative analysis.

Spectrographic Laboratory with trained staff maintained to train your operator.

Distributor for Applied Research Laboratory spectrographic equipment.

PRACTICAL—SIMPLE—
ACCURATE—ECONOMICAL

Write

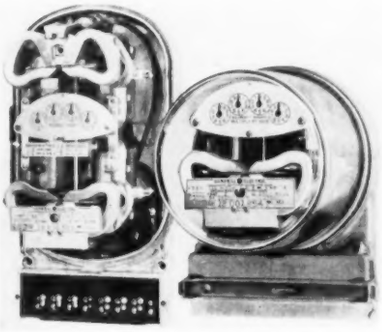
HARRY W. DIETERT CO.
9330 Roselawn Ave.
Detroit, Michigan

Enclosed Rotameters

Outward appearance "more like an instrument," lower prices made possible by simplifications, and a ball float—which is one of these simplifications—characterize new "Universal" model of the Rotameters now produced by this maker (see *Instruments*, Oct. 1937, page 250). Illustration shows details of new construction, with tube enclosed in polished brass case and knurled brass nuts holding the end fittings. These also exemplify simplification, being standard polished-copper pipe fittings. New model is made in sizes from $\frac{1}{4}$" (illustrated two-fifths actual dimensions, overall length 16") to $2\frac{1}{2}$". Smallest unit can indicate as low as 0.05 cc./min. of liquid, and largest 55 g.p.m.; for gases, 1 ml./min. to 8 ft.^{3}/min. Pressure limits: 100 lbs./in.^{2} for sizes up to $\frac{3}{4}$" and 50 lbs./in.^{2} for sizes from 1" to $2\frac{1}{2}$".—*Fischer & Porter Co., 110 West Penn St., Germantown, Philadelphia, Pa.*

Two- and Three-phase Watthour Meters

The weight and size of two- and three-phase polyphase watthour meters has been materially reduced without sacrifice of mechanical and electrical characteristics. In the two-phase meter (right) the two elements, acting on the same disk, are smaller than heretofore and, because of their low inherent errors and the applied overload compensation, are said to be highly accurate. The disk, mounted on an aluminum-alloy shaft, is novel in that it is constructed for minimum interference. It is made up of several radial-slotted laminations, assembled with the slots staggered and separated by very thin insulation. The three-element meter (left) has two electric elements acting on the lower disk and the third element on the upper disk. —*General Electric Co., Schenectady, N. Y.*



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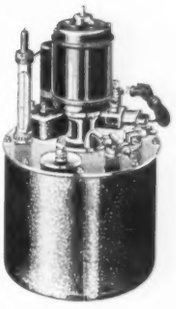

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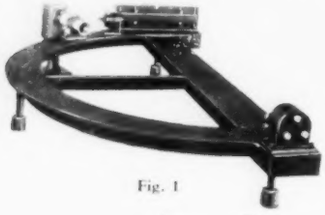

Fig. 1

Fig. 2

resolution and dispersion with high sensitivity and speed. An arc or a high-voltage spark gap is obtainable to volatilize the alloy being tested. The camera utilizes a standard 35-mm. motion picture film in a 100-foot roll. Each exposure is 12½" long covering 2200 A.U.

A projection comparator (Fig. 2) enables the operator to project on a screen the spectra of known and unknown samples for rapid identification of elements present in qualitative analysis. The photo-densitometer comprises battery, voltage-compensating device and microammeter to read line intensity for quantitative analysis at the same time that qualitative analysis is made.—*Harry W. Dietert Co., 9330 Roselawn Ave., Detroit, Mich.*

Speed Ratio Control

The gyroscope is being used to stabilize a position regulator used to control the speed of one motor with respect to a reference speed. In a brick plant, for instance, the speed of a cutter on a brick forming machine must be controlled to cut equal lengths of brick from clay extruded at a very slow rate. In the new system, a small wheel rides on the extruded clay and drives one side of a differential; the other side is driven at a constant reference speed. If the two speeds do not match, the regulator responds to the differential and effects a corrective action. The function of the small gyroscope is to "give an anti-hunting action to the regulator as it anticipates any deviation from the reference position." Since relatively little power can be obtained from the friction drive wheel operating on the clay, large amplification is provided in the regulating system so that (1) the relatively large power required by the output motor can be controlled, and (2) high sensitivity is imparted to the control system.—*Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*

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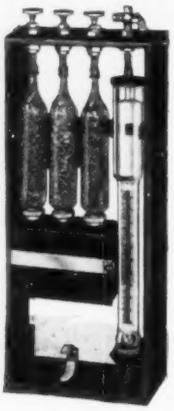

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By G. W. STUBBINGS
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THIS BOOK reflects the amazing development in large-scale power transmission which has taken place in Great Britain during the past decade under the Government sponsored "Grid" system. The subject matter falls into five main divisions: (1) protective transformers, (2) the interconnection of these transformers to form protective circuits, (3) relays, (4) modern methods of protecting electrical apparatus, and (5) the testing of relays and protective circuits . . . The volume is liberally illustrated; the material is logically presented in a lucid manner; and the whole provides a concise treatment of a subject upon which it has heretofore been difficult to collect comprehensive data without extensive reading in diversified publications."

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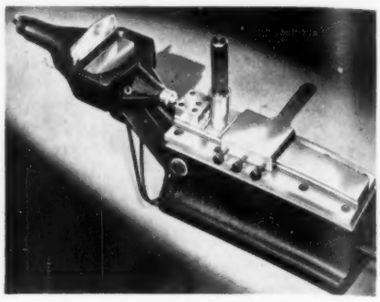
Inspection Gage for Taper Plug Gages

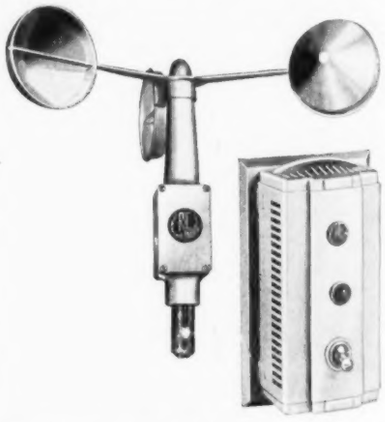
For the checking of tapered plug gages, a new inspection instrument has a horizontal bed, at one end of which is an adjustable anvil and at the other a visual



gage. Precision gage blocks to the true small diameter are stacked on the bed. Placing a standard gage roll tangent to each end of the stack, the anvil is then set so that it and the gaging element are both in contact with the stack of blocks and rolls—the shadow on the gage dial then standing at zero. Replacing the blocks and rolls with the plug gage allows its variation from true diameter to be read directly. Illustration shows the checking of the small diameter of a taper plug gage by means of the new inspection gage. Note standard rolls on either side of plug gage.—*Sheffield Gage Corp., Dayton, Ohio.*

Wind Indicator

A remote-reading system is announced consisting of a cup-type anemometer transmitter and of a receiver which emits both audible and visible



signals in time with primary-element rotation and at such a rate that the number of signals in one minute corresponds to miles-per-hour of the current to which rotor is exposed. By reason of use of ball bearings, etc., maker's accuracy guarantee is 1 m.p.h. throughout range. Receiver has toggle switch to turn off electricity supply except when a reading is desired to be taken. Supply is 6-volt storage or dry-cell battery, or through resistor from higher-voltage d.c. supply, or through bell-ringing transformer from commercial a-c. supply.—*Julien P. Friez & Sons, Baltimore St. at Central Ave., Baltimore, Md.*

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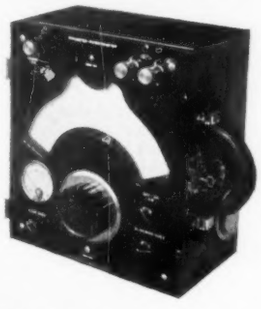

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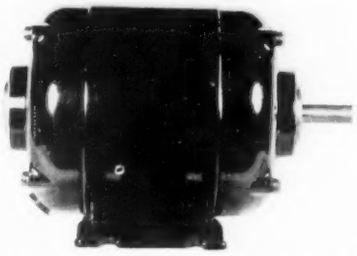
Voltmeter-Megohmer

New "Model DM" Megohmer has been re-designed so that it may be used as a portable a-c. and d-c. voltmeter with a range of 600 volts. Older instruments

had a range of 0-100 megohms, with a 500-volt generator for insulation resistance measurements, with an extra binding post to permit use as a portable dc. voltmeter. Redesign provides an auxiliary scale to permit of using the instrument for both a-c. and d-c. voltage measurements. — *Herman H. Sticht & Co., 27 Park Place, New York City.*

Electric Tachometer

This new remote-indicating system employs an a-c. generator instead of a d-c. magneto. Design features of "Model 341" generator are said to be: no commutator



or brush, no sliding contacts, all windings water- and oil-proof, totally-enclosed case. Generator is 4¾" long and of 3 5/16" O.D., with 5/16" shaft extending out 1". According to manufacturer it can be operated for years without atten-

tion. "Model 43" indicator is of electrodynamometer type, can be furnished in sizes up to 12" scale length. Scales are available with calibrations in r.p.m., f.p.m., m.p.h., c.p.s., etc. Combined accuracy of system is "well within 2%" under the most extreme conditions."—*Electric Speed Indicator Co., 14618 Bayes Ave., Lakewood, Ohio.*

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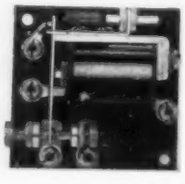
Vehicle Speed and Acceleration Recorder

Principal added feature of new Model R-734-M Special Speed Recorder is a chart-speed-change device. Normal speed of the 6.5 cm. (approx. $2^9/_{16}$") inkless type strip chart is such that a 20-ft. roll under normal conditions is equivalent to 500 miles of vehicle driving. In new

model, however, an auxiliary electric motor (6 or 12 volts) drives the chart at a speed of approx. 3" per min. when switched on. This motor may be switched on manually for acceleration and braking tests, or it may be switched on automatically during brake applications exceeding a given pressure, by connecting motor to the stop-light switch actuated by brake pedal. Speed measuring mechanism (Hasler Tel, Switzerland) is of chronometric class, conjugating type (see *Instruments*, July 1931, pages 379-386; August 1931, pages 423-425) employing a positive measurement method, and hence is a "primary tachometer" giving a reading of directly-measured revolutions divided by directly-measured time, without being affected by temperature, inertia, magnetic fields and other common sources of error. Charts are available with m.p.h. or f.p.s. scales—all with uniform graduations. A "fifth-wheel" drive, clamping on front or rear bumper, is available for use in important test work where it is preferred to the use of the vehicle's speedometer take-off drive.—*R. W. Cramer & Co., Inc., 67 Irving Place, New York City.*

Sensitive Relay

A new a-c. sensitive relay is available with single-pole, double-throw contacts. Use of nickel alloy in the magnetic circuit is said to make possible a high degree of sensitivity, good contact torque at pull-up and a crisp constant drop - out. Coils are available for currents from 1.5 to 430 milliamps. Relatively large knurled nuts facilitate adjustments of silver contacts and armature spring tension. Bakelite base, approxi. 2" square, may be mounted in any position without altering its performance.—*Ward Leonard Electric Co., Mount Vernon, N. Y.*



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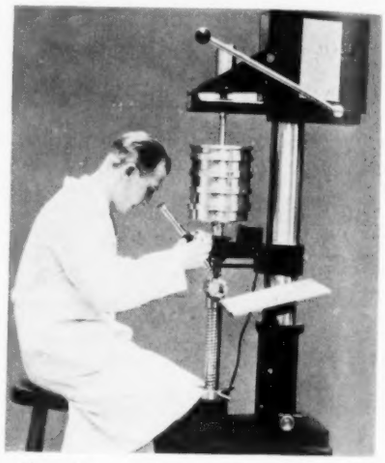

chine has a direct-acting, dead-weight loading system, without lever. Hollow main column contains an oil-dash arrangement which applies load in a steady manner, maintains it for given period and releases it again to zero, entire test cycle being fully automatic and adjustable within wide limits. After load is thus automatically lifted, indentation produced is immediately ready to be measured: no need of lowering test-piece and swinging measuring microscope into special position. Microscope reads directly to 0.001 mm. on a large micrometer drum, and measurements at right angles can be taken without moving the test-piece. Machine is said to be suitable also for hardness tests of plastics. Indenters: Vickers diamond pyramid; Brinell balls of 1, 2, $2^1/_2$ mm. diam.; Clearances: about 12" for height of test-piece; about 6" from indenter to machine frame; Test loads: from $1^1/_2$ to $62^1/_2$ kg., in increments of $^1/_2$ kg.—*Herman A. Holz, 167 East 33rd St., New York City.*

Plug-in Resistors

Originally developed several years ago for use in the maker's plant as working standards, resistors are now offered in the plug-in type of construction, for maximum flexibility as to resistance values and range. With this method, 20 resistors provide a range of 1 to 100,000 ohms in 1-ohm steps. Units consist primarily of double silk or cotton-covered manganin wire bifilar wound on Bakelite bobbins and then housed in a standard four-prong UX radio tube base. They are available in a resistance range of 1 to 10,000 ohms employing manganin wire. Maximum accuracy is 0.1% for units above 10 ohms, and 0.25% for units between 1 and 10 ohms. Resistors made of nichrome wire may be had above 10,000 ohms and up to 100,000 ohms, with maximum accuracy of 0.25%. Maximum continuous safe power ratings of units is 1 watt.—*Clarostat Mfg. Co., Inc., 87 N. Sixth St., Brooklyn, N. Y.*

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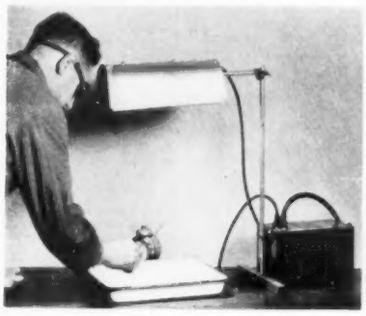
A new "highly flexible" source of ultra-violet radiation, "Type H Uviarc," consisting of a quartz-tube mercury vapor arc mounted within a special reflector on a portable laboratory stand, is operated from any 120-volt or 220-volt a-c. line through a portable auto-transformer



supplied. Sealed mercury vapor tube has high radiation characteristics in both near and far ultra-violet zones; has a rated operating life of 2,000 hours. New unit is self-starting, is also "universal-burning," operating with equal efficiency in any position. The 6" arc tube operates at 360 watts out of a 410-watt input supplied to the auto-transformer, or 87%. Radiation at all wave-lengths in the ultra-violet region is stepped up accordingly:

Wavelength Lines and Bands	Spectral Intensities (Microwatts per cm.2 at 1m.)
14,000-3,800 A.U.	380
3,800-3,100 A.U.	180
3,100-1,850 A.U.	300

Quartz tube is mounted within a reflector hood, chromium plated for high ultra-violet reflection, concentrating radiation within a 90° angle, and so designed that two standard 6½" × 6½" filters can be slipped in place for selective filtration. If desired, unit can easily be built-in as a part of permanent equipment for industrial radiation. For test work requiring portability, auto-transformer comes equipped with a removable handle, and the supporting stand for reflector fits in place in bracket on end of transformer to from a self-supporting unit.—*General Electric Vapor Lamp Co., 481 Eighth St., Hoboken, N. J.*

Color Matching Lamp

"Model F" is a small booth-like bench model of the artificial-daylight-source introduced several months ago (see *Instruments*, June 1937, page 150) but has similar illumination characteristics. Illumination is due to an electric discharge in carbon dioxide. Spectral distribution is close to that of cloudy north sky light and to international standard curve. This chromaticity remains unchanged by reason of continuous supply of fresh gas, which is the basic feature of the method. New models are 22" long, 12" wide, 18" high, and available as follows:

Model	"F-1"	"F-2"	"F-3"
Watts	250	425	625
Foot-candles	40	80	125

footcandles being average of readings taken at normal working distance, as in comparing textiles.—*Barkon-Frink Tube Lighting Corp., 23-10 Bridge Plaza, Long Island City, N. Y.*

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A highly convenient instrument for the measurement of the strength of permanent magnets by comparison with standard. Described in circular 425.

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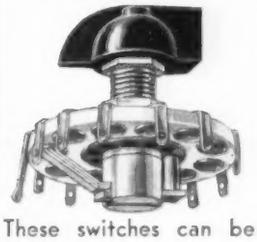

SINGLE OR MULTI-DECK

These switches can be supplied with various number of contact points, are compact and rugged with very low contact resistance. Modifications of standard switch can be made to suit various requirements. Switches can be supplied with resistors mounted.

Resistance Range from 1 ohm to 10 megohms

The Shallcross wire wound resistors are used for decade assemblies, accurate to 1/10, 1 2, 1 4, and 1%.

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SHALLCROSS MFG. CO.
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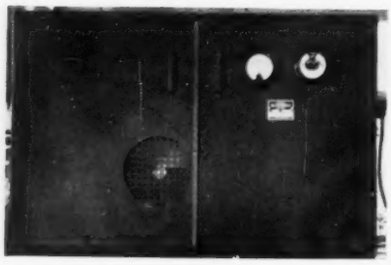

Gas Detector and Automatic Alarm

Newly-developed "B&B" continuous automatic gas detecting and alarm system operates on continuous-sampling principle, a suction pump drawing a number of samples in rotation, through flexible connections and lines reaching points to a maximum distance of 150 feet. Maximum number of zones from which continuous samples are drawn is 15. System is available in simpler form, however, for use where only one continuous sample is desired to be analyzed, and where neither remote instrument-panel nor remote alarm is required. Three principal component units of system are: detector and alarm (illustrated) operating on electrical response to chemical or colorimetric reaction; control panel with instrument, meter, signal light, etc. (vapor-proof when required); multi-point gas-gathering assembly with pressure and vacuum pumps, relief valves, air filters, motor and starter (explosion-proof when required). Essential parts being standard equipment, replacements are obtainable from local supply houses. Total operating and maintenance costs are said to be negligible, servicing being required every 10 to 20 days, depending on nature of installation. Sensitivity is adjustable—in a hydrogen sulphide application, for example, alarm may be made to operate on a concentration of 0.0015% minimum, or 0.10%. Range depends on nature of gas, vapor or dust to be detected. Usual lag between sampler and detector is 20 sec.—*B. O. Bushnell, 541 N. Kings Rd., Los Angeles, Calif.*

Profile Projector

Suitable for the average tool and instrument shop, new Leitz Simplified Profile Projector is intended for inspecting small parts, gears, templets, gages, etc. Part to be inspected is placed on a compound table having micrometer adjustment 1" × 1" in both directions. Its contour, magnified 10 to 100 × (up to 200 × in special cases) is projected on a drawing board directly in front of instrument. Operator compares outline with standard drawing and can measure deviations from standard by means of two micrometer screws attached to cross table, or by means of gage blocks inserted in case of greater dimensions such as center-to-center distances. Instrument may be placed on workbench or a suitable cabinet. It requires no darkroom. Principal aim of its designers is said to have been to provide a simple method of placing small parts directly on the glass top by their own weight, obviating need for holding fixtures. Taps, thread gages, hobs and other cylindrical parts

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Wheelco Instruments Co.
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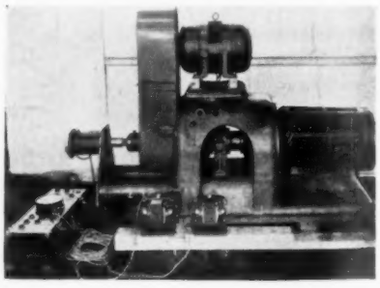
are taken between centers and can be checked not only for form, lead and angle, but for concentricity. Table swivels 12° in either direction to provide sharp images of screw threads up to 12° helix angle. When instrument is not in use, drawing board slides back into base, protecting drawing and saving space.—*George Scherr Co., 128 Lafayette St., New York City.*

Machine-balance Analyzer

Placing the balancing of rotors "on location" on a quantitative basis, a new balancer, which can be carried in two suitcases, reduces the number of trial runs to two or three and simplifies the determination of correction weight position and amount to instrument readings and elementary arithmetic. Basic method



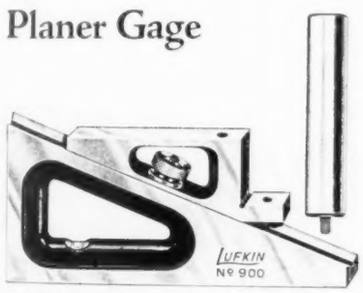
was described in article by F. C. Rushing, *Instruments*, Sept. 1935, pages 228-231; but balancer now available is simpler. A sine-wave alternator, little larger than an office-fan motor, is connected to the shaft of the vibrating machine. The stator of this alternator can be shifted at will to control the phase relation. A vibration pickup is held against the vibrating body. The output of the pickup, suitably amplified, is fed to the voltage coil of an indicating wattmeter; the output of the sine-wave alternator too goes to the current coil. By shifting the alternator stator to obtain zero and maximum wattmeter readings, the position and amount of correction weights for selected planes can be quickly determined. New balancer is said to be good for the most complicated cases of vibration. Illustration shows it applied to a centrifugal casting machine.—*Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*

Video-signal Source

For television experimenters, designers and testers, a new type of video signal source obviates all need of waiting for days or weeks to tune in on desired television images, and of figuring out

signals of unknown scanning techniques. The "Phasmajector" (Greek for image emitter) is a modified form of cathode-ray tube wherein, in place of the usual fluorescent screen swept by the cathode-ray beam and glowing to form an image, there is a metallic plate on which is printed the desired picture or test pattern. Tube includes also a collector electrode, in addition to the conventional "gun" and deflecting electrodes. Operating principle is the variation of secondary emission from image plate. Varying voltage output, picked up by the collector electrode and fed to the grid of a video amplifier, is highly stable and is said to be "of much better quality than can be obtained from a photoelectric mosaic pick-up tube" because of absence of capacitance effects. Circuits and principles involved are part of maker's "simplified high-definition" television system, the receiver of which need be little more than a high-grade short-wave receiver with a cathode-ray tube in place of the usual loudspeaker. "Phasmajector Type 1" has same operating voltages as the DuMont 34-XH 3" cathode-ray tube, has on its plate a line drawing of Abraham Lincoln.—*Allen B. DuMont Laboratories, Inc., Upper Montclair, N. J.*

Planer Gage



"Master" planer and shaper gage added to maker's line will properly handle many jobs beyond the limits of other planer gages, it is said. Proper cut is obtained by setting the gage to a micrometer, a surface gage or caliper, then bringing planer tool in contact with it. With the extension, tool settings from $\frac{1}{4}$" to 9" can be made; without it, the range is $\frac{1}{4}$" to $6\frac{1}{2}$". This gage serves also as an adjustable (sliding) parallel. It can be employed with a sine bar for grinding angles; also with gage blocks for building up work on a surface plate and for transferring measurements, with an indicator. Slot in which slide travels is beveled as well as ground, the bevel preventing all side play when slide is tightened, at any location by clamp nut. Gage can be used on base, on end, also flat on either side, as both slide and nut are within outside width of base and both sides are ground square with the working edges. Base is $\frac{5}{8}$" wide, $5\frac{1}{8}$" long, and fitted with level.—*Lufkin Rule Co., Saginaw, Mich.*

Exposure Meter

Designed for use over a wide range of illumination levels in taking either still or motion pictures, this new exposure meter employs same photocell as used in G-E light meter. Novel feature is a direc-

tional hood: when pointed at a normal scene, full horizontal angular width of camera is included, but a much narrower vertical angle is included, to minimize error caused by strong sky light. This hood is provided also with a slotted cover which, when opened, increases sensitivity by 10 to 1. In extremely low illumination, hood may be removed and another increase in sensitivity of approx. 10 to 1 obtained. Direct-reading scale gives *f* values and exposure readings for most popular films. Values for emulsions of other speeds can be obtained by using calculator (on hood) which translates foot-candles into shutter speeds for any film and lens aperture. With hood removed, instrument serves as a light meter for use in home, office or factory.—*General Electric Co., Schenectady, N. Y.*

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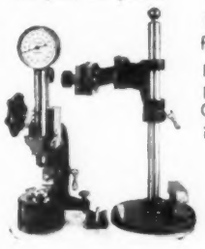

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Cathode-ray Tube Application Check-lists

CLASSIFICATION, SPECIFYING ESSENTIAL and OPTIONAL AUXILIARIES

By RALPH R. BATCHER

Radio engineer; cathode-ray and electronic application specialist, Hollis, L. I., N. Y.

This table, or chart, lists a number of tests in various technical fields where cathode-ray equipment has proved of value. In most of these applications auxiliary equipment is necessary in addition to the tube itself and its operating power supply. For the sake of simplicity, this equipment is listed alphabetically in the table below, and the various items are referred to in the main table by their key letters.

There is however some leeway in the type of apparatus used in many of the tests, and doubtless other set-ups will suggest themselves to engineers.

In the main list, obvious variations are shown as "A or B"—indicating that either item "A" or item "B" can be used.

It will be seen that most of the commercial oscillographic equipment that is now available contains items A, C, and D.

Where an item appears in parentheses, such as (N), this indicates that its use is optional.

In many applications deflection amplitude must be calibrated, and various standardizing units may be required. In others relative amplitudes are checked against known characteristics of samples.

EQUIPMENT ASSOCIATED WITH APPLICATIONS LISTED

A—Linear time base.
B—Circular time base.
C—Vertical deflection amplifier, suitable for the frequencies involved.
D—Horizontal deflection amplifier, suitable for the frequencies involved.
E—Vibration pick-up, with amplifier.
F—Synchronous time base, controlled by the device under test.
G—Audio oscillator (usually beat frequency).
H—Intermediate-frequency oscillator.
I—Radio-frequency oscillator.
J—Synchronous frequency changer (wobbler).
K—Photocell (with amplifier).
L—Sound microphone with amplifier.
M—Connections required to modulation grid of the cathode-ray tube.
N—Camera or photographic recorder.
O—Special units to effect time base synchronization.
P—Pressure pick-up, with amplifier (for low frequency or steady pressures).
Q—Special conversion units to transform functional effects into deflection potentials.
R—Radio receiver (in some cases of special design).
S—Magnetization coils, and flux search coils.
T—Deflection amplitude control means.
U—Electronic switch.
V—Radio-frequency pick-up coils.
W—Phase shifting apparatus.
X—SPECIAL CATHODE-RAY TUBE

I. ACOUSTICS AND VIBRATIONS

a. Binaural location of sound.....B, L, L
b. Effectiveness of sound insulation.....A or B, G (J) L
c. Frequency discrimination of auditory equipment.....A, G, J
d. Loud speaker tests.....A, G, J, L
e. Sound analysis.....A, L
f. Vibration analysis.....A, E, (L)

II. AUTOMOTIVE AND AIRCRAFT

a. Aeronautic engine synchronization.....B, O, Q
b. Cylinder pressure indicator.....A or B, P, O, (N)
c. Detonation.....A or B, P, O
d. Dynamic balancing of rotating parts.....B, E, O, (Q)
e. Engine speed.....G, (C), (Q)
f. Fuel efficiency.....A or B, P, O, (O)
g. Ignition, timing and adjustment of breaker points...A, Q, O
h. Ignition, efficiency of coils, plugs, etc.....A, (N), (O)
i. Noise studies.....A, E or L
j. Radio interference suppressor adjustments.....A, (O), R
k. Riding comfort studies, vertical acceleration tests, on seats, tires, springs, etc.....(A), E, (N), Q
l. Roadbed shocks due to heavy hauling.....A, P
m. Timing.....A, Q, (O)
n. Viscosity of lubrication oils.....A, Q

III. CHEMICAL ANALYSIS

a. Chemical production of light.....X
b. Dielectric analysis.....A, G
c. Over-voltage studies.....A or B, Q
d. Reaction time.....A or B, Q
e. Viscosity.....A, Q

IV. EDUCATIONAL DEMONSTRATIONS

a. Acceleration of gravity.....Q
b. Determination of small time intervals.....B, G, (M)
c. Electrical generators, theory of.....C, D
d. Electrical motors, theory of.....C, D
e. Harmonic analysis.....A, G
f. Mutual induction and coupled circuits.....G, I, (U)
g. Phase relations in electrical circuits.....B, W
h. Phase relations in mechanical circuits.....Q, Q
i. Photocell characteristics.....A, C
j. Photometric measurements.....A, K
k. Stress-strain relations.....P, Q, O
l. Resultant of forces.....Q
m. Velocity of light.....B, K
n. Velocity of sound through various materials.....A or B, G, L
o. Velocity of electricity through filters, lines, etc.....B
p. Zero balance or null indicator.....C

It is evident that many of the items that are listed in other sections of this table may also serve in lecture demonstrations.

V. ELECTRICAL COMMUNICATIONS

a. Dielectric losses in underground cables.....C, G, W
b. Electrolysis studies, direction, intensity and frequency of ground currents.....A or B, C
c. Filters, characteristics of delay.....B, G, (J), (M), (N)
d. Filters, matching of terminal equipment to.....G, (U)
e. Frequency characteristics of appliances.....A, C, J
f. Frequency multiplier.....X
g. Fuses, operating time of.....A or B, (M)
h. Grounds, effectiveness of pole line.....C, A
i. Lightning, intensity, frequency, and duration of.....A, T
j. Loading balance of phantom circuits.....C, D
k. Monitoring high quality telephone lines.....A, C
l. Overload tests in circuit breakers.....B, (M)
m. Phase relations in networks.....B, W
n. Relay operation.....B, (M), (U)
o. Repeaters, tests on telephone line.....A, C, G, (J)
p. Tubes, characteristics of electron.....A, (T), (U)
q. Timing of dial pulses.....B, G, (M)
r. Tests on power factor of condensers.....C, G, (W)
s. Waveform distortion of telegraph pulses.....A, G
t. Wareform converter for facsimile receiver.....A, M, O, R

VI. ELECTRICAL POWER PLANT MAINTENANCE

a. Dielectric losses in cables.....C, G (W)
b. Frequency comparisons .....G or H or I
c. Fuse operation time.....A or B, G, M
d. High voltage peak voltmeter.....T
e. Lightning surge studies.....A, T
f. Load balance between phases.....U
g. Location of leakage on transmission lines.....B, C, (R)
h. Location of radio interference sources.....R
i. Phase relations and power factor determinations..B, W, (U)
j. Power factor correction.....C, W
k. Power network synchronization.....C, (U)
l. Phase rotation, direction of.....C, (U)
m. Synchronization of rotating machinery.....U
n. Study of ground currents.....A or B, C
o. Timing of relays, and circuit breakers.....B, M
p. Remote indicator for some complicated recording .....B, E or K or P or Q

VII. ELECTRICAL MANUFACTURING

a. Continuous comparison of product with standard.....Q, U
b. Indicator, quick-acting for production testing.....A, T, (U)
c. Location of source of noise in product.....E or L
d. Rapid delineation of characteristic curves.....C, D, U

VIII. GEOLOGICAL AND GEOPHYSICAL STUDIES

a. Surveys using sound pressures.....A, C, E, (L), (N)
b. Surveys using electromagnetic waves.....A, S, (N)
c. Surveys using electrical resistance measurements..A, C, (N)
d. Seismography .....C, E, (N)
e. Well or rock drilling, sound, vibration or pressure studies .....E or L or P or Q

IX. MAGNETIC INSPECTION

a. Hysteresis tests .....S
b. Permeability tests .....S
c. Check for flaws and fissures by magnetic analysis.....S
d. Coercivity .....S

X. MANUFACTURING OPERATIONS

a. Micrometric indicator .....A or B, (K), (P), Q
b. Measuring eccentricity .....B, E or Q
c. Measuring small time intervals.....B, G, (M)
d. Instantaneous pressures on machine tools.....A or B, P, (Q)
e. Dynamic Balancing of rotating parts.....B, E, O, Q

XI. MEDICAL AND BIOLOGICAL

a. Nerve action current indicator.....A, C, (N)
b. Electrocardiograph .....A, C, (N), (O)
c. Organic sound diagnosis, (stethoscopy).....A, L
d. Electroencephalograph .....A, C, N
e. Electromyograph .....A, C, N
f. Effects of cathode rays on tissues.....X

XII. MILITARY

a. Ballistics (velocity of bullets).....A or B, K or L or Q
b. Ballistics, (pressures reached during recoil).....A or B, O, P
c. Fatigue of metals.....(E), (Q)
d. Inspection of guns for flaws by magnetic methods.....A, S
e. Inspection for flaws by sound when struck.....A, C, E or L
f. Magnetic compass, unaffected by vibration.....X
g. Mapping, radio transmission of diagrams.....R, Q
h. Radio Compass .....R
i. Sound Interpretation, direction of source.....B, L
j. Telautograph .....R, Q
k. Ultrasonic communication recorder.....A, C, Q
l. Weather studies, studies of direction of static.....R

XIII. MUSICAL

a. Harmonic studies .....A, D, G, L
b. Instrument quality determination.....A, L, (G)
c. Piano tuning .....A, L, G, (Q)
d. Pitch determination or comparison.....A, L, G
e. Voice analysis .....A, L

XIV. PHYSICAL RESEARCH

a. Dielectric field mapping.....C, Q
b. Electron microscope X
c. Magnetic field mapping.....S
d. Measurement of e/m.....X
e. Source of electron emission in air.....X

XV. PROPAGATION OF RADIO WAVES

a. Analysis of static.....A, R
b. Directivity of signals (deviation from great circle path).....B, R, O
c. Fading .....A, R, O
d. Studies of radio echoes.....B, C, I, (N), R, O
e. Wave polarization .....B, R
f. Wave propagation and reflection phenomena.....B, R

XVI. RADIO RECEIVER SERVICING

a. Auto-radio noise elimination studies.....A, R
b. Auto vibrator adjustment.....A, C
c. Automatic frequency control circuit tests.....A, I, (J)
d. Automatic volume control circuit tests.....A, I
e. Detector overload characteristics.....A, I or H
f. Amplifier distortion .....A, G or H or I
g. Frequency characterics .....A, G or H or I
h. Hum elimination.....C
i. Interference analysis .....A, R
j. Neutralization .....A, C
k. Peaking of i-f. circuits.....A, H, J
l. Selectivity curves .....A, H or I, J
m. Superheterodyne tracking problems.....I, J
n. Tuning indicator X

XVII. RADIO TRANSMITTERS

a. Determination of parasitic oscillations.....A, V
b. Keying speed, and study of keying transients.....A, V
c. Modulation percentage .....V, C, (G)
d. Neutralization .....A, V
e. Modulation linearity .....V, C, (G)
f. Radio frequency peak reading voltmeter.....C
g. Overload indicator .....A, C or V

XVIII. RADIO RESEARCH

a. Ammeter, radio frequency.....C
b. Ammeter, peak reading.....C
c. Bridge measurement indicator.....C
d. Characteristics of vacuum tubes.....C, D, F, (U)
e. Decrement .....A, C
f. Dielectric losses in insulating materials.....C, D
g. Frequency characteristics of amplifiers.....A, G
h. Hum analysis C
i. I-f. transformer characteristics .....A, H, J
j. Loud speaker tests.....A, G, L
k. Noise analysis .....A, L
l. Overload distortion in amplifiers.....A, G
m. Phase relations .....C, D, W
n. Power diagrams .....C, D, (W)
o. Resistance curves of volume controls.....F, C
p. Resonance indicator C
q. Shorted turn indicator.....A, S, (W)
r. Transformers, frequency characteristics.....A, G
s. Wattmeter, radio frequency.....C, D, (W)
t. Wave analysis .....A, C
u. Voltmeter, radio frequency.....C
v. Voltmeter, peak reading.....A, C
w. Volume indicator .....A, C

XIX. SOUND FILM RECORDING

a. Light valve X
b. Visual monitor .....A, C
c. Tone flutter and "wows".....A, O, Q

XX. TELEVISION

a. Image-former for receiver.....X
b. Studio pickup camera.....X
c. Video-signal source.....X

Determination and Control of Heating Rate

By R. J. SMITH

Instructor, Michigan College of Mining and Technology, Houghton, Michigan

CONSTANT heating-rate control is of importance in many investigations in physics, physical chemistry and physical metallurgy. In precision thermal analysis, for example, constant heating rates are almost a necessity, and in dilatometry many apparent anomalies are explained if all changes in slope of the dilation curves can be relied upon to be significant. Constant heating-rate control assures that all such changes are true indices of structural changes.

Recently several methods have been described for controlling the heating rate of laboratory furnaces. One device makes use of a differentially wound spiral resistor in series with the furnace.[1] Another apparatus, devised at the Michigan College of Mining and Technology, permits the control of either temperature or heating-rate.[2] The latter control, designed by Dr. C. T. Eddy, was based upon the dilating wire principle of Chévenard. This apparatus has been further developed and improved, since greater accuracy and flexibility were found to be necessary than were obtained in the original apparatus or in the newer spiral resistance control. By increasing the sensitivity through improved relay control and by improving the mechanical design, much greater accuracy of control can now be obtained.

The purpose of this article is to demonstrate that automatic constant heating-rate control may be obtained by a combination of the principle of the dilating wire control and the temperature-amperage relations of a furnace, and that the setting of the control may be predetermined. The subject will be considered in the following order: 1st, the design and construction of a laboratory furnace for a specific laboratory application; 2nd, the accurate calibration of the furnace; 3rd, the calibration of the dilating wire of the control under the conditions required for the operation of the furnace; 4th, the correlation of the furnace characteristics, dilating wire calibration, and the mechanical dilating factors of the control assembly, with a view to obtaining a desired heating rate on the furnace.

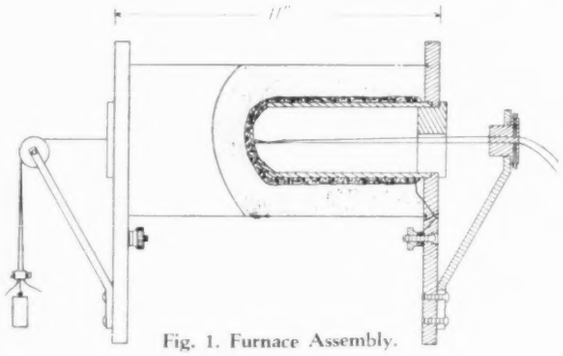

Fig. 1. Furnace Assembly.

[1] R. L. Wilcox & J. R. Bossard. A Self Recording Apparatus for Thermal Analysis. *Metals & Alloys*, Vol. 7, Sept. 1936, pages 221-224.
[2] C. T. Eddy, F. W. Vigelius & E. C. Davis. Furnace Temperature and Heating-rate Control by Dilating Wire. *Instruments*, Vol. 8, July 1935, pages 174-176.

CONSTRUCTION OF FURNACE

The specifications of a laboratory furnace for thermal analysis depend upon the specific application and hence vary considerably. Desirable heating and cooling char-

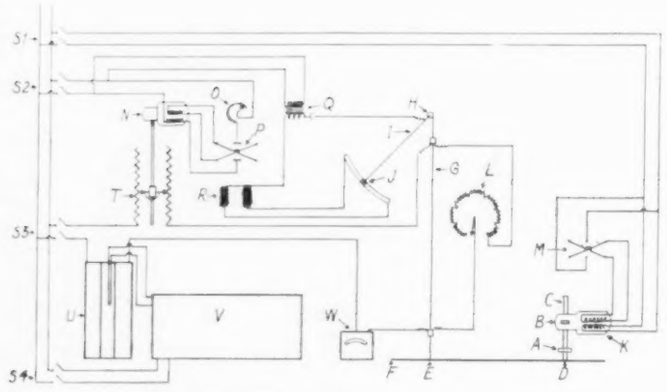

Fig. 2. Schematic diagram of apparatus.

A—Calibrated dial.

B—Gear, threaded internally (30 threads/inch).

C—Screw, 30 threads/inch.

D, E, F—Lever.

G—Dilator wire.

H—Pulley.

I—Contactor arm.

J—Primary relay contacts.

K—Constant speed, 110-volt a-c. motor with combined (900:1) speed reducer.

L—Shunt resistor, for decreasing sensitivity of control and to permit the control of furnaces which draw more than 700 watts. (Not used in obtaining the data for this article.)

M—Reversing switch.

N—110-volt series motor with combined 252:1 speed reducer.

O—Series speed control resistor.

P—Two double pole-single throw magnetic relay switches operating as a 110-volt reversing switch.

Q—Rectifier, 110-volt a-c. to 6-volt d-c.

R—6-volt primary coils of two magnetic relay switches.

S_1—Constant-speed dilator motor switch.

S_2—Rectifier and series motor switch.

S_3—Furnace switch.

S_4—Micromax recorder switch.

T—Variable resistor in series with dilating wire, ammeter and furnace.

U—Furnace.

V—L&N Micromax potentiometric recorder.

W—Ammeter.

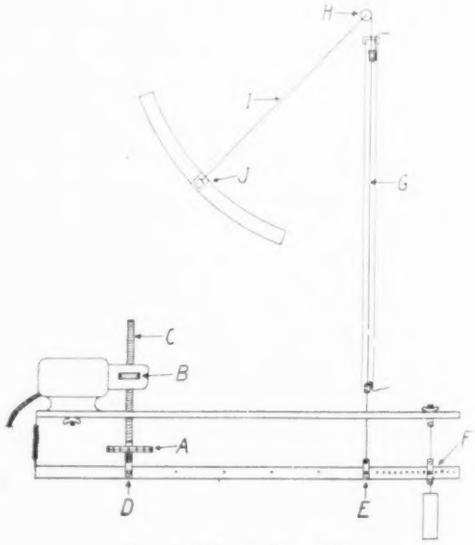

Fig. 3. Dilator Assembly.

A—Calibrated circular disk.

B—Gear; threaded internally (30 threads/inch) to fit screw C, and milled externally to work from the motor speed reducer worm.

C—Screw, 30 threads/inch.

D, E, F—Lever: F—Fulcrum; DF — Force Arm; EF—Resistance arm.

G—Dilator wire, No. 22 B&S Advance, length 27".

H—Contactor arm pulley, effective radius ¼".

I—Contactor arm, 27".

J—Primary relay contacts, operating on 6 volts d.c.

acteristics of such furnaces may be obtained through control of the size and heat capacity. These factors in turn are affected by the area of cooling surface, the thickness of insulation, etc. For the purpose of this article, assume the requirements for the construction of a particular furnace to be as follows:

1. Size—11" L. × 2.2" I.D. × 5" O.D.
2. Capacity—600 watts, cold, on 110 volts.
3. Heating rate (from 0 to 1000° C) at least 5° C. per min.
4. Cooling rate (between 1000° and 250°) at least 5° C. per min.

It has been found empirically that a satisfactory gage for the resistor elements of small laboratory furnaces is that of a wire which on being suspended horizontally in air is heated to approximately one-half the furnace temperature when a current corresponding to the limiting capacity of the furnace is passed through the wire. Accordingly No. 22 B&S gage Nichrome V wire was selected. This wire will heat to approximately 530° C. when 5.5 amperes are passed through it. Since its resistance is 1.017 ohms per foot, the proper element length is about 19.5 ft. with the power supply at 110 volts. Sil-O-Cel insulating material was chosen because of its low-packed density (resulting in lower total heat capacity) and good thermal insulation. The resistor was wound evenly on an alundum core, allowing two closely-wound turns at each end to compensate in part for temperature gradients from the end to the center of the furnace. The entire wound core was given a light coating of alundum cement. The assembled furnace is shown in Fig. 1.

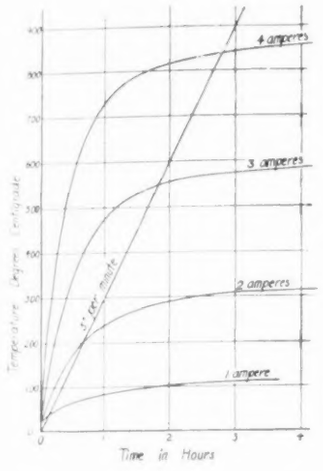

Fig. 4. Time-temperature curves.

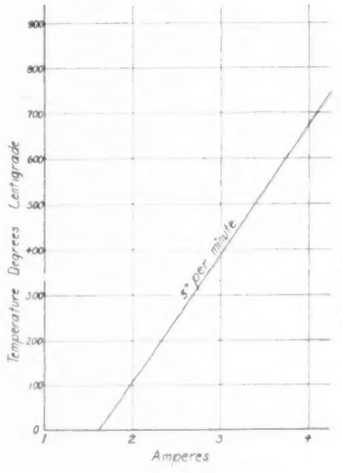

Fig. 5. Temperature-amperage

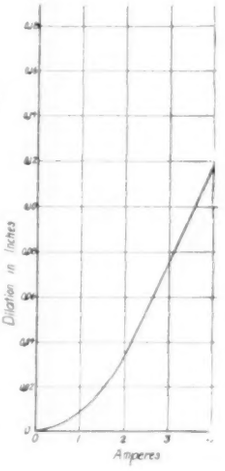

Fig. 6. Dilation-amperage.

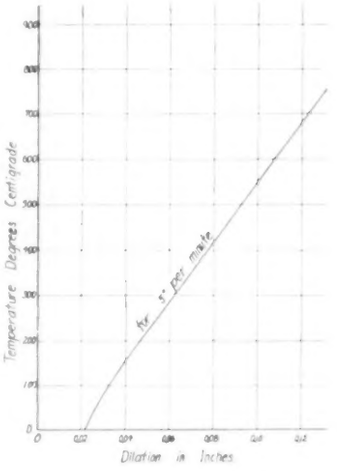

Fig. 7. Temperature-dilation.

CALIBRATION OF FURNACE

Since commercial a-c. supply voltage fluctuates, it was necessary in making this calibration to compensate for the resulting irregularity. For this purpose the dilating wire assembly was used to keep the voltage drop across the furnace constant. This control has been used previously for similar purposes and for temperature and heating rate control.[2]

The calibration of the furnace necessitates obtaining time-temperature curves at definite amperages. For each different amperage through the furnace, the time-temperature curves starting at approximately 20° C. were automatically recorded by means of an L&N Micromax recorder. Four amperages were used—1, 2, 3 and 4. The resulting curves, replotted, are shown in Fig. 4.

A straight line representing a heating rate of 5° C. per min. was drawn in Fig. 4. Points on the time-temperature curves showing this same slope of 5° C. per min. represent data from which the temperature-amperage curve in Fig. 5 was drawn. When applied to this particular furnace, the temperature-amperage relation should result in a constant heating-rate of 5° C. per min., the desired heating rate.

CALIBRATION OF DILATING WIRE

To calibrate the dilating wire—that is, to determine its dilating characteristics at the amperages and under the conditions employed—the ratio beam, the dilating wire, and the relay contactor portion of the thermo control were used. This assembly is shown in Fig. 3. With the wire G cold, the screw C was turned through stationary gear B until the relay contactor rested in neutral position at J. The graduated disk A was then set at zero position and a current of 1 amp. was passed through dilation wire G. The dilating wire system was allowed to come to thermal equilibrium, and then screw C was turned until relay contactor I was again at neutral position, at which time the number of revolutions of screw C was noted from disk A.

The current through G was increased successively to 2, 3, and 4 amps. and the same procedure was repeated for each current value, the total revolutions of disk A being recorded. The dilation-amperage curve, Fig. 6, was then obtained by correlating these current values with the dilation, which in turn was obtained from the revolutions of disk A, the beam ratio EF to DF (4:20), and the number of threads (30) per inch of screw C.

CORRELATION OF DATA

From the temperature-amperage curve, Fig. 5, and the amperage-dilation curve, Fig. 6, the temperature-dilation curve shown in Fig. 7 was plotted. It now remains merely to choose from this temperature-dilation curve the extension of the dilation wire for the range of temperature over which constant heating rate is desired, and, from the straight time-temperature line (Fig. 4), the time required to heat (at 5° C. per min.) over the range chosen. The relation of these values gives the wire dilation speed per minute, which is then obtained by adjusting the beam ratio EF to DF.

In following this procedure it may be seen from Fig. 7 that the dilation is 0.0870" (0.1110—0.0240) when the temperature range is 20 to 620° C. At a heating rate of 5° C. per min. this temperature range of 600°

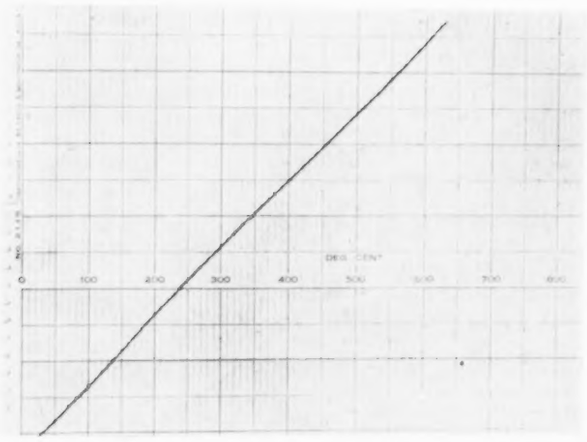

Fig. 8. Time-temperature curve from constant heating rate test.

will require 120 minutes, or a wire extension of 0.00072″ per minute.

The starting current from any temperature must be chosen from the temperature-amperage curve of Fig. 5. This starting current is the amperage necessary to start the furnace heating at a predetermined heating-rate from the starting temperature. In the present case, 1.7 amps. is the proper value, starting from 20° C. The constant-speed motor works through worm reducers in such a manner that the worm working on gear *B* turns at 2 r.p.m. The gear *B* has 20 teeth, and the screw *C* has 30 threads per inch, so that the vertical movement of the screw *C* is 0.00333″ per min. (when the screw is clamped and prevented from turning). The nearest beam ratio which will give the proper dilation speed (from tables already made for beam ratios available on the instrument) is 5.5″ : 25.5″; or 5.5/25.5 × 0.00333 = 0.000719″ per minute.

TEST OF PROCEDURE

To verify the accuracy of the foregoing procedure a complete test was made using the same furnace. The control data were obtained entirely from the calibration of the furnace and of the dilating wire.

With the ratio beam of the thermo-control set at 5.5″ : 25.5″ as deduced, the furnace current was set at 1.7 amps. The thermo-control was then put into operation. Sufficient time (one or two minutes) was allowed for the dilating wire to attain thermal equilibrium.

The heating-rate curve of the furnace was recorded automatically by the L&N Micromax. See Fig. 8. The average heating rate between 20° C. and 620° C. is 5.2° per min. This represents a maximum error of 4% of the desired value of 5° C. per min. Slight changes in slope over the temperature range covered may be observed. The constant speed dilation of the No. 22 B&S gage Advance dilating wire makes it impracticable to allow for changes in the coefficient of expansion of the dilating wire as its temperature increases.

Fig. 9 is a photograph of a cooling curve of Armco iron taken automatically and with heating rate control. The general uniformity of the record and the sharpness of the transitions may be noted. The lower transition is that of nickel. Comparison of this record with that previously published[3] clearly demonstrates the improvement obtained by, and the importance of, heating-rate control in this type of work.

SUMMARY

The purpose of this article is to demonstrate that automatic constant heating-rate control may be predetermined from the combination of the principle of the dilating wire and the temperature-amperage relations of a furnace. Data are presented showing the practical applicability of the method. The larger significance of the findings is that constant heating rates reflect their importance into the consistency of thermal measurements made in laboratory furnaces and into the increased accuracy and dependability with which results may be interpreted.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to Dr. C. T. Eddy, Associate Professor of Metallurgy, Michigan College of Mining and Technology, for the criticisms offered and assistance rendered in this work.

[3] C. T. Eddy. An Automatic Apparatus Assembly for Thermal Analysis. *Review of Scientific Instruments*, Vol. 4, 1933, pages 200-205.

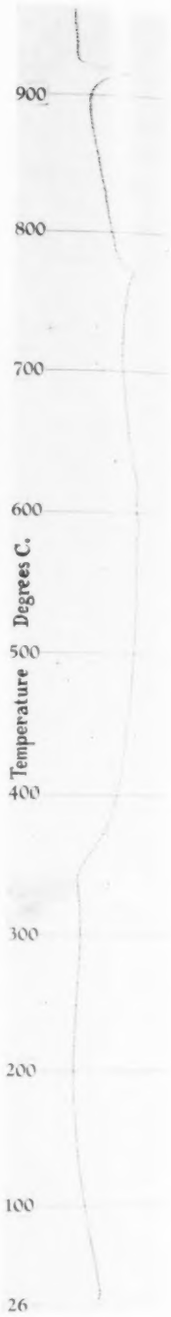

Fig. 9. Thermal differential record for Armco iron.

Required Reading for Instrumengineers

The Engine Indicator—Its Design, Theory and Special Applications. By K. J. DeJuhasz. A mine of information for all engineers who have to investigate forces and motions—not only in engines but in many other applications. Cloth, 5½x8¼ inches, 313 pages, $3.75.

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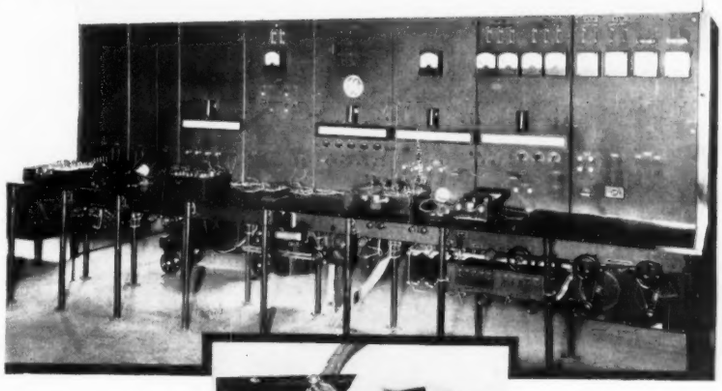
Equipment for Precision Calibration of Electrical Instruments

By W. D. EGNOR
General Engineering Laboratory, General Electric Co., Schenectady, N. Y.



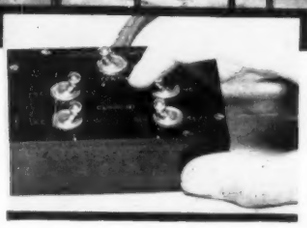


Fig. 1. The Calibration Table
Fig. 2. Contactor Control Box

INTRODUCTION

INCREASING demand for accurate electrical measurements in science and in manufacturing, together with continued progress in instrument development, necessitate improved standardizing equipment and technique. To meet these needs and to provide for the future, a table for the precision calibration of secondary standards and special instruments has been built and is located in the General Engineering Laboratory of the General Electric Company, in Schenectady. This table represents a major advance in this type of equipment. Some of its outstanding features are versatility, compactness, safety, convenience, with uniform and sufficient illumination.

GENERAL DESCRIPTION

The table, Fig. 1, is 16 ft. long, with framework of steel. The flat table top, 30" high, is covered with battleship linoleum. Curving 5 to 6 ft. above it is the white reflector providing shadowless illumination. On the eight panels are mounted the various switchboard instruments, incoming switches, scales for the electrodynamometer instruments and the binding posts for current and voltage. Electrical instruments such as voltmeters, wattmeters, ammeters, within a voltage range of 0 to 900 volts and current range 0 to 200 amps., at any frequency up to 3000 cycles, as well as frequency meters, with corresponding ratings, may be checked with a precision of 0.02% or better. This precision is well within the accuracy limits of the instruments, most of which have an accuracy in the order of 0.1%.

In the design of this table, determination of the best location for the various controls and standards was accomplished by first building a full-size wooden model of it. The galvanometer scales and the various controls and instruments were represented by actual-size paper models. These models were pinned to the vertical panels and the actual instruments and standards were placed on the flat table top. Then laboratory men, who would later use this table, placed themselves at the various stations and went through the procedure of calibrating the instruments, the controls being moved about until the most suitable location was secured. In this way, the best positions for the various controls and standards were determined. The drawings were made from this wooden model.

LIGHTING ARRANGEMENT

Adequate illumination of instrument scales is the first requirement. If lights are placed too close to an instrument, however, they will create a temperature gradient in the instrument — a common cause of heating errors. A second requirement, therefore, is proper illumination: not only adequate for eyesight but practically "cold and shadowless." This is accomplished by a system of indirect lighting consisting of a curved reflector mounted above the table with the necessary lamp bulbs out of sight of the operators. The reflector is painted a flat white and is constructed so that the intensity of light is uniform over the whole area of the table top. The dispersing effect of the white surface makes the occurrence of annoying shadows practically impossible. In reading a mirror scale instrument, the image of the white surface in the mirror makes an excellent background for the pointer.

The average amount of light on the table top is 50 foot-candles. The maximum deviation from this value is only three foot-candles, except at the extreme ends where the intensity of light is 40 foot-candles.

SWITCHING METHODS

The calibration or checking of most instruments requires a great deal of switching. For example, it is necessary in the calibration method used for 200-amp. a-c. ammeters to switch from a.c. to d.c. and also to reverse the d.c. Ordinarily, this would be accomplished by operating large switches by hand. In some cases this would necessitate moving from one end of the table to the other in order to operate these switches. Instead of using switches which are operated manually to control these circuits, contactors are used. Similar contactors are also used to control the potential circuits. These contactors in turn are operated by 22-volt relays controlled by toggle switches arranged in a small box (Fig. 2).

Binding posts to which the potential and current circuits are connected are located at various convenient places on the panel above the flat table top. These circuits are energized with a-c. or d-c. sources of power, and the polarity of either the current or potential circuits may be reversed by operating the proper toggle switch on the contactor control box. There are two of these contactor control boxes, each with a flexible lead and plug; and each may be plugged in at either of two

different stations. One of these contactor control boxes has switches on it which control both the potential and current circuits, while the other one controls only the potential circuits. When both of these boxes are plugged in at the same time, the potential control is taken away from one station position, leaving only the current control. This makes it possible to use both ends of the table at the same time; for example, a voltmeter may be calibrated at one station while an ammeter is calibrated at the other.

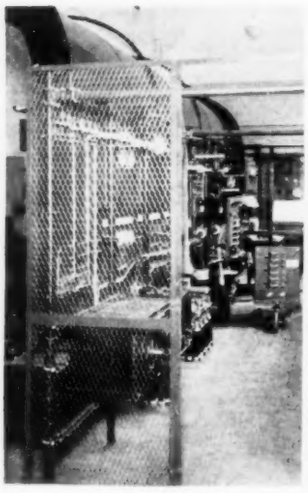


Fig. 3. Rear view of the calibration table showing battery truck, transformers, auxiliary switching equipment, safety cage.

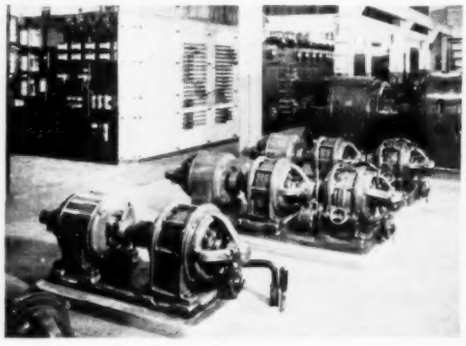


Fig. 4. Some of motor-generator sets in Laboratory power plant. Two "three-unit" sets near foreground.

Fig. 5. Incoming feeder panel and starting panel for the large d-c. generator.

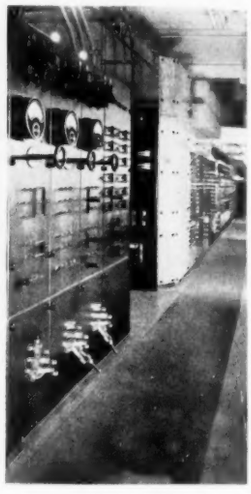


Fig. 6. Switchboard in the Laboratory power plant.

SAFETY

The safety of operation of any apparatus cannot be over-stressed. On this table, lines which may be at high potential enter the table through switches located at the top of the panel, out of reach except by means of a long insulated rod. Switchboard instruments are mounted beneath these switches and connected across these lines, continually indicating which lines are energized and at what level.

From these switches, some of the lines go to the various field control rheostats on the table, while others are wired through the switching contactors previously mentioned to the current and voltage buses on the table.

The space back of the table (Fig. 3) is enclosed by a safety cage with doors which are kept locked. In this space are located the transformers, storage batteries for direct current, auxiliary switching equipment, the galvanometer, and the electrodynamometers. The galvanometer and electrodynamometers are placed on a shelf mounted on the outside wall of the building so as to obtain a minimum of vibration. Control rheostats are so placed as to be readily accessible from the rear, insulated rods preventing the possibility of accidental personal contact by an operator using the table.

POWER SOURCES

Both the a-c. and d-c. power supplies are isolated from the general laboratory system by the use of transformers and batteries, respectively. This permits the use of grounding connections most suitable to the work being done at the table itself.

The a-c. sources of potential and current are obtained from separate transformers which are energized by an alternator. These transformers have several ratios which are easily changed by means of a simple switching arrangement in order to obtain the desired voltage and current ranges.

Frequencies from 6 to 3000 cycles at any power factor from zero to unity, leading or lagging, are obtained from the various machines in the Laboratory power plant. Also, by the use of a special harmonic generator set, any desired wave-form may be obtained up to and including the seventh harmonic, with the fundamental in the range of 20 to 60 cycles.

To supply power for the majority of the calibration work a so-called "three-unit" motor-generator set (Fig. 4) is used. This equipment, located in the Laboratory power plant, has two identical alternators on the same shaft. The stator of one of these alternators can, by means of an auxiliary motor controlled from the calibrating table, be rotated into any position with respect to the stator of the other alternator. By using one alternator for current supply and the other for potential, any desired power factor can be obtained for wattmeter calibration. These alternators are of special design and their windings are so constructed that the wave-form is exceptionally free from harmonics. These machines have been found especially suitable for laboratory calibration work where good wave-form over a wide range of frequency is essential.

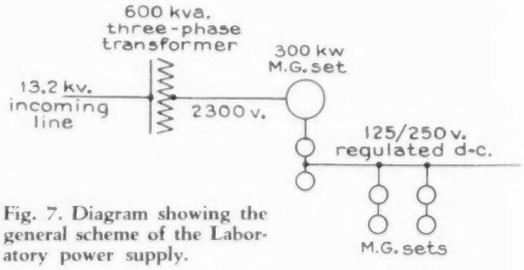


Fig. 7. Diagram showing the general scheme of the Laboratory power supply.

In order to obtain steady voltage and current, and constant frequency, all the motor-generator sets in the Laboratory power plant (Figs. 5 and 6) are excited from two large d-c. generators (Fig. 7). The voltages of these generators are controlled to 0.2 volt by means of voltage regulators. Any one of the motor-gener-

sets in the power plant may be controlled from the calibrating table.

The harmonic generator set, previously referred to for obtaining various wave-forms, has a "fundamental" alternator and third, fifth, and seventh harmonic alternators on the same shaft. Each harmonic generator is equipped with means for rotating the stator in the same manner as in the three-unit sets previously mentioned.

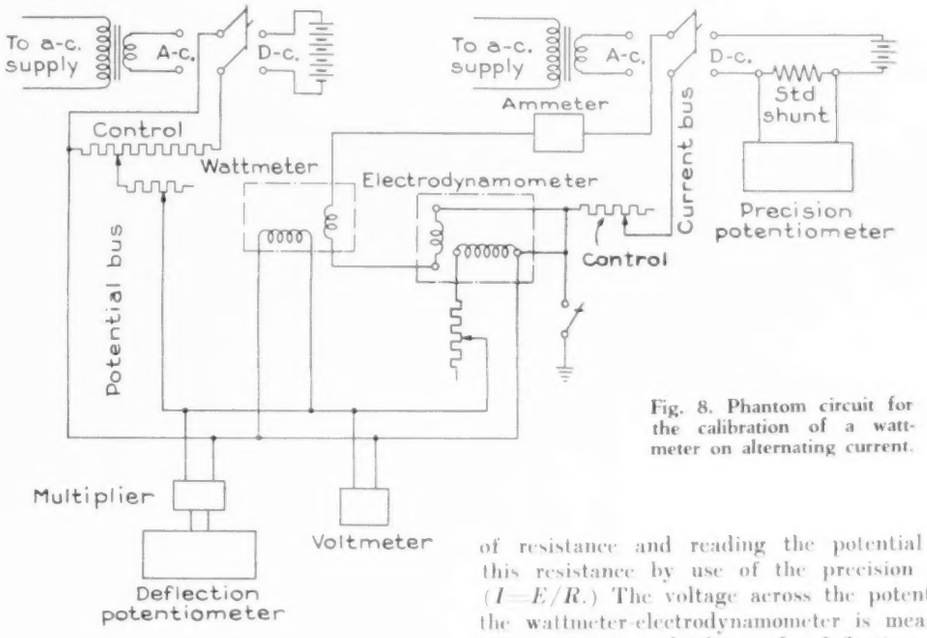


Fig. 8. Phantom circuit for the calibration of a wattmeter on alternating current.

By suitably interconnecting the "fundamental" and harmonic generators, it is possible to produce a complex wave, the harmonics of which are controllable both as to magnitude and phase.

To use these motor-generator sets it is necessary for the table to have at least two generator field controls. The current taken by the various generator fields may range from 0 to 50 amp. In order to eliminate heavy-current rheostats, fixed resistors are located in the calibrating table to cover this large range of field currents. Snap switches place the groups of these resistors in parallel with the rheostat control so that the desired voltage may be obtained.

CALIBRATION PROCEDURE

In order to illustrate the general procedure in the use of this table, a detailed description of the calibration or checking of a wattmeter at 60 cycles is given, it being assumed that the motor-generator set of the desired rating has been connected directly to the calibrating table from the Laboratory power plant.

In checking a wattmeter on alternating current, the method known as the transfer method is used. This necessitates the use of a "transfer standard," generally a carefully constructed astatic reflecting electrodynamometer having known characteristics and equally accurate on either a.c. or the mean of direct and reverse d.c. This is located in the enclosure at the rear of the table.

The essential scheme underlying such a method is as follows: (1) Calibrate a given watt point on the transfer standard (astatic reflecting electrodynamometer) on direct and reverse d.c. (2) Change *immediately* to an alternating current source of the frequency and power factor desired for calibration. (3) Using the electrodynamometer reading previously secured by Item 1, determine the indication of the wattmeter under test. This procedure is repeated at every point on the instrument for which a check is desired.

In checking the wattmeter, a phantom circuit (Fig. 8) is used. The current in the current coil of the wattmeter electrodynamometer (the transfer standard) is measured by passing this current through a known value of resistance and reading the potential drop across this resistance by use of the precision potentiometer ($I=E/R$.) The voltage across the potential circuit of the wattmeter-electrodynamometer is measured by use of a resistance multiplier and a deflection potentiometer. In order to obtain the desired deflection, adjustable resistance is used in series with potential coil of the electrodynamometer. This resistance is selected to have a low phase angle, to keep errors due to this source to a negligible value.

A-c. ammeters are calibrated by a similar transfer method. Instead of using an electrodynamometer for the transfer standard, a thermocouple is often used. This thermocouple is also equally accurate on either a.c. or the mean of direct and reverse d.c.

Frequency meters are calibrated by holding the frequency constant at the desired scale point and computing the cycles elapsed during a known interval of time.* Special motor-field controls are incorporated within the table for convenient control of frequency.

CONCLUSIONS

It might appear that a calibration table on which such varied work may be done with such great accuracy would be complicated to operate. However, this table is comparatively simple to operate because of its unique system of controls, all of which are clearly marked. Any person who has a fundamental knowledge of instruments and calibrating circuits can quickly learn how to operate it safely and efficiently.

Although the table was put into operation less than three years ago, careful studies have shown that the increased output made possible by its use has compensated for practically its entire capital outlay. With the greater volume of work done tending to liquidiate its original cost, the increased accuracy obtainable appears as a dividend which benefits both the standardizing group and the final instrument user.

*S. C. Richardson, The Calibration of High Sensitivity Frequency Meters, *General Electric Review*, Vol. 39, October 1936, pages 501-503.

Early Penetration Hardness Methods

By S. R. WILLIAMS

Professor of Physics, Amherst College

The earliest record we have of someone deliberately going to work to establish a means for measuring hardness is a publication by Réaumur[1]. His method was similar to that practiced by most boys who wish to show the superiority of the steel in the blades of their pocket knife. Two boys take their respective knives and let the edge of one blade cut into the edge of the other. The knife with the larger "nick" is the softer and, therefore, the "poorer" of the two. No doubt that centuries before hardness was made a subject of scientific enquiry, the relative quality of two swords had been measured by the same method.

Réaumur shaped right-angled prisms, as in Fig. 85, from the two different materials to be compared. These two prisms were set with their axes at 90° to each other

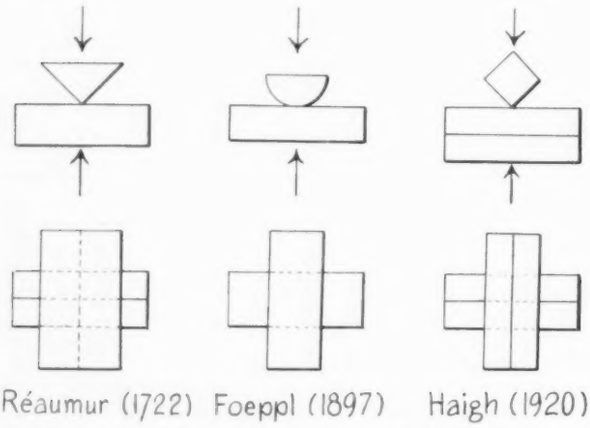


Fig. 85. Various forms of indenters used in hardness testing.

and with the 90° angles of the prisms cutting into each other. From the depth of the two indentations made, the relative hardness of the two materials could be judged. The pressure for both prisms was, of necessity, the same.

A procedure similar to that of Réaumur has been followed by Foeppl[2] and Haigh[3]. Foeppl used two cylindrical test pieces whose axes were placed at right angles to each other and then pressed together in a clamp or press. The positions of the two test pieces are shown in Fig. 85. Foeppl measured the areas, A, of the flattened surfaces at the points of contact. This area divided into the total force used in pressing the cylinders together gave Foeppl his number for hardness. He found that F/A was a constant.

In preparing his samples for testing Foeppl cut two small plates from the material to be measured. These plates then had one flat side ground so that it became a cylindrical surface whose diameter was about 20 mm. (see Fig. 85). In order to determine the diameter of the circular area of permanent deformation, Foeppl covered the cylindrical surface with a thin layer of fine lamp black and found that the area of disturbed lamp black was identical with the area of permanent deformation of the cylinder. This was ascertained by carefully wiping off the lampblack from half of the indentation and comparing the location of the edge of the imprint in the lampblack with that of the permanent depression in the cylinder.

Haigh has recently revived these methods. Instead of triangular prisms with 90° angles he substituted square prisms. The relations between the two samples are shown in Fig. 85. Haigh took as his measure of hardness the ratio of the total force applied to the length L of the damaged edge of the prism. F/L = constant.

It should be noted that Réaumur compared the relative hardness by taking prisms of two different materials. Foeppl and Haigh used two prisms of the same material, but were in a position to derive numbers which should stand for hardness values: F/A = constant and F/L = constant.

These methods measure resistance to penetration, or it may be said that they measure resistance to permanent deformation. The amount of penetration or the amount of permanent deformation is taken as a measure of this resistance. Area, depth, length, width, bending, stretching, twisting and compression may furnish a measure of penetration or of deformation.

Before proceeding to discuss modern experimental methods for testing hardness by the indentation process, attention should be called to four outstanding papers[4,5,6,7] which discuss the problem of hardness testing from a theoretical point of view.

HERTZ'S PAPER[4]

Hertz's paper starts out with the proposition—and this is followed by the others—that in the case of a penetration method, the problem is most easily solved when the penetrator and the penetratee have surfaces of definable and ascertainable geometrical figures, for example, spheres and planes.

AUERBACH'S PAPER[5]

Auerbach starts his paper by reviewing various scratch methods and comes to the conclusion that the right step is being taken in developing the static (indentation) method as over against the dynamic (scratch) method. Auerbach is led to the definite question. Is the definition of hardness as defined by the scratch sclerometer correct in its principle? He answers this question by saying "I believe that this is by no means the case," and the reason he gives for not favoring the scratch method is that hardness, when determined by the scratch method, is much too complicated a conception to be used as a basis for the definition of that property. He believes that there are too many concomitant effects which have

[1] R. A. F. Réaumur, L'art de convertir le fer forgé en acier, et l'art d'adoucier le fer fondu, ou de faire des ouvrages de fer fondu, aussi finis que de fer forgé. Michel Brunet, Paris, 1722, pages 566-587. Reprinted in part, with résumé by F. Cournot, in *Revue de Métallurgie, Mémoires*, Vol. 19, 1922, pages 447-468.

[2] A. Foeppl, Über die mechanische Härte der Metalle, besonders des Stahls. *Annalen der Physik*, Vol. 63, 1897, pages 103-108.

[3] B. P. Haigh, Prism Hardness. *Proceedings Institution of Mechanical Engineers*, Vol. 2, 1920, pages 891-913.

[4] H. Hertz, Über the Berührung fester elastischer Körper. *Journal für die reine und angewandte Mathematik*, Vol. 91, 1881, pages 156-171.

[5] F. Auerbach, Absolute Härtemessung. *Annalen der Physik und Chemie*, Vol. 43, 1891, pages 61-100. (An excellent translation of this paper by Carl Barus will be found in the Annual Report of the Board of Regents of the Smithsonian Institution, July 1, 1890 to June 30, 1891. This was reprinted in the Miscellaneous Documents of the House of Representatives for the First Session of the Fifty-Second Congress, Vol. 43, 1891-1892, pages 207-236.)

[6] E. Meyer, Untersuchungen über Härteprüfung und Härte. *Physikalische Zeitschrift*, Vol. 9, 1908, pages 66-74.

[7] S. L. Hoyt, The Ball Indentation Hardness Test. *Transactions American Society for Steel Treating*, Vol. 6, 1924, pages 396-420.

connection with hardness and therefore becloud the issue. Auerbach says, "The second difficulty encountered is the dependence of the results of the sclerometer on the degree of sharpness of the marking stylus . . . It is quite obvious that the styluses of different apparatus cannot have been identically sharpened, and that the stylus of the same apparatus will soon become blunted by continued use. Measurements into which this serious discrepancy necessarily enters cannot be comparable among themselves."

It may be recalled that Bierbaum emphasized this point in connection with his standard instrument and pointed out that his diamond edge could be duplicated with all the accuracy obtainable in any sclerometer or indentation method. In fact the duplication of a diamond edge, such as Bierbaum proposes, may, when referred to a definite axis of the crystal, be more standard than the grinding of a steel ball for use as an indenter, because in the theory it is assumed that the steel ball does not suffer distortion in the process of indentation. From the actual process[8] of producing steel balls it must be evident that the steel ball varies in its elastic properties in different directions as shown by the variations in hardness illustrated in Fig. 86. It would appear that the ball indenter is as subject to variations as in the diamond stylus of a sclerometer. In either method it is assumed, of course, that the test is based on a permanent deformation due to plastic properties of the specimen tested and not due to disruptive deformations.

Again quoting Auerbach: "It has already been stated that Hertz investigated a definition of hardness which is mathematically exact, and which does not conflict with the prevailing notions of the quality. He replaces the indefinite point by a spherical surface; or to state this more correctly, since the point is after all a spherical surface of very small radius, Hertz uses a stylus with a radius of curvature large enough to be measurable."

In these four theoretical papers there seem to the general reader to be two outstanding points to be considered: (1) penetrators whose dimensions are known and whereby the amounts of stress and strain set up in the points of contact may be ascertained; (2) the criteria for hardness tests.

[8] E. K. Hammond, Manufacture of Steel Balls, *Machinery*, Vol. 23, 1917, pages 753-760.

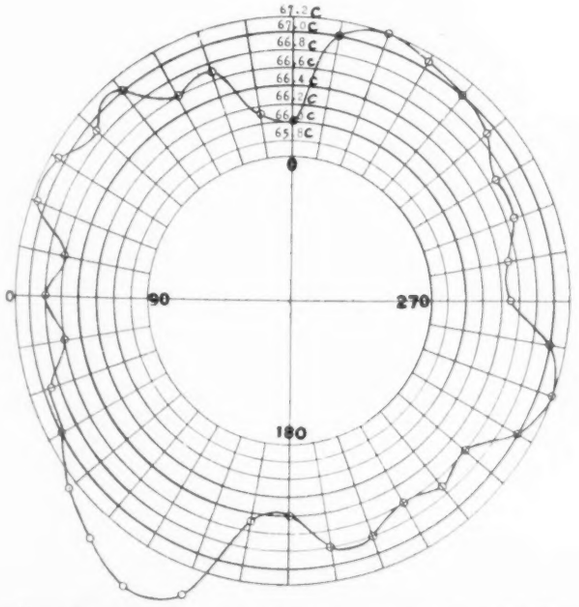


Fig. 86. Variations in the hardness of a ¾" steel ball as measured every 10° of arc around the equator of the ball.

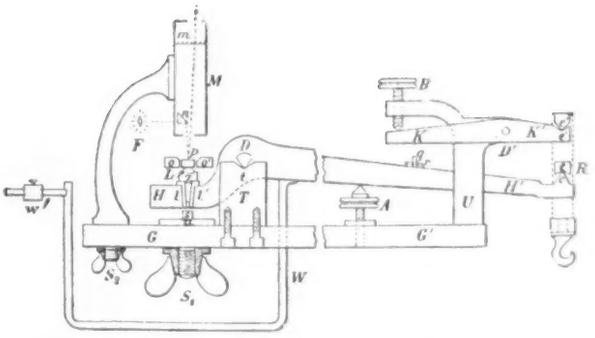


Fig. 87. Auerbach's hardness tester as used in measuring the hardness of glass.

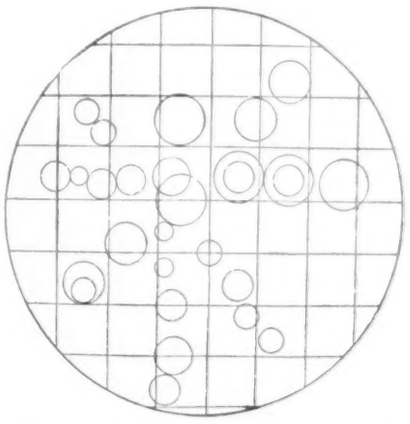


Fig. 88. Imprints of Auerbach's spherical indenter on the surface of a plate of glass.

When a steel ball, for instance, just touches a plane surface, the contact is a point which spreads out in an ever-widening circle as the pressure is increased. Over this circle of contact the pressure will not be uniform but will be greatest at the center of this circle. The criterion for the hardness of a body as given us by Hertz is, that it is measured by "the least value of the (central) pressure per unit area necessary to produce permanent set (or rupture) at the center of the impressed surface." Hertz reduces hardness to a quality of elasticity, *i.e.*, he measures hardness by the force just necessary to produce the initial permanent deformation. He had some grounds for believing this as shown in Fig. 26 (April 1937 instalment).

Auerbach thought he was confirming Hertz in this point of view, but what he really showed was, that "the harder of two bodies is the more elastic, hardness increasing less rapidly than elasticity." Other factors, therefore, must come in to complicate the determination of hardness. It simply brings out once more that no one number or one factor is sufficient to express the hardness of a body as ordinarily defined.

Auerbach follows his theoretical discussion with actual measurements and, as he thinks, in line with Hertz's theory. It is virtually a ball penetrator with which he works. Fig. 87 shows a drawing of the instrument. A glass lens—a spherical indenter—is forced up against a plane surface of glass by a load attached to the long arm of lever, H H′. Inasmuch as the first indication of permanent deformation is most easily seen on substances which show the first permanent set by a rupture, Auerbach turned his attention to such substances as glass and transparent crystals. As shown in Fig. 87, vertical illumination made it possible to watch the advent of the first permanent set as more and more load was added to

the scale pan. The limits of elasticity must be gradually approached and not overstepped. The first appearance of permanent is the signal to hold the pressure from further increase. Fig. 88 gives a picture of the impressions for various curvatures of the indenter. Auerbach finally confesses that Hertz's theory and practice do not agree.

On the assumption that both the convex indenter and the plane surface indented have equal hardness, Auerbach finds that the rupture always occurs on the plane surface and never on the surface of the curved indenter. Auerbach ran into the difficulty discussed previously, that hardness as measured by the indentation method is a function of the form of the indenter.

MEYER'S PAPER[6]

By 1908 the Brinell (steel ball indenter) hardness tester had become a widely used means for measuring the suitability of metals for certain purposes. This led Meyer of the Materials Testing Laboratory at the Imperial School of Technology, Charlottenburg, Germany, to emphasize the need for an extensive study of the rela-

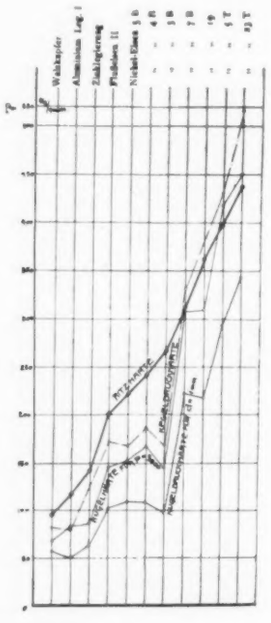


Fig. 89. A comparison of scratch hardness with those as measured by ball and cone indenters.

tions between theory and practice as used with the Brinell machine. Meyer also felt that comparisons should be made between indentation methods as practiced by Foeppl, Brinell and others; between indentation methods of the cone type of indenter as suggested by Ludwick and between various scratch methods as practiced by Mohs, Martins and their followers.

The 1908 paper by Meyer is a valuable addition to the literature of the subject of hardness. He built up an equation between the load P applied and the diameter of the circular impression produced by the ball. This relation is given in the following form:

$$P = a\,d^n\ ,$$

where P is in kilograms per square millimeter, d the diameter of the impression in millimeters, and a and n are constants for the material under examination. Two metals can thus be compared for penetration hardness when one knows the constants of the material or the whole course of the hardness curve.

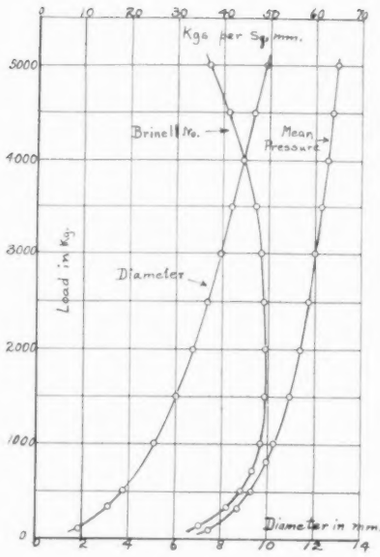


Fig. 90. Studies on annealed copper made by Hoyt by means of a ball indenter.

If one uses the true mean pressure,

$$p_m = \frac{P}{\pi\, d^2/4}$$

the hardness of two metals can be compared either at constant load or at constant diameter of impression for a given degree of loading.

In Fig. 89 are shown some comparative values of hardness determined by ball and cone indenters and by the scratch method. The cone and ball penetration methods offer quite a satisfactory comparison, but only where large contrasts in hardness occur for the penetration method can one say that corresponding variations occur for the scratch method. *The scratch and penetration methods are not measuring the same property!*

Meyer also discusses the inadequacies of the penetration method.

HOYT'S PAPER[7]

Auerbach discussed Hertz's theoretical paper and added experimental data thereto. In a similar fashion Hoyt does the same for Meyer's paper. Hoyt starts off by saying: "The purpose of this paper is to present a rational analysis of the ball indentation test, and to show the manner in which such an analysis can be applied to certain fundamental problems in hardness testing."

One point of particular interest in Hoyt's paper is the clearness with which he discusses the various ways in which permanent deformations are brought about. This point has already received considerable attention in preceding chapters and will be discussed still more later on. Quoting one paragraph, Hoyt says: "Scratching implies that the metal is deformed beyond its elastic limit; in brittle materials by an amount sufficient to produce cleavage, and in ductile material, sufficient to produce plastic flow. Scratching further implies (1) local rather than general application of the load, which in turn implies (a) local deformation with (b) restricted flow of metal during deformation; (2) that the load is applied by or through a substance which is harder than the metal under test; and (3) that deformation is confined to the metal under test."

Hoyt comes to the conclusion that the ball indentation test meets the conditions developed in the theory with sufficient exactitude that it can be regarded as a true

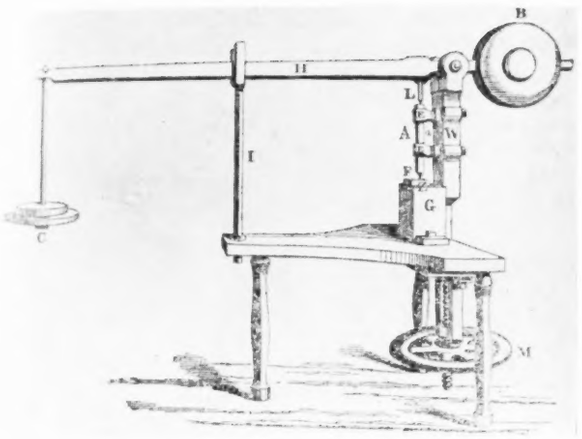


Fig. 91. Hardness tester developed by Calvert and Johnson in 1859. A penetration method.

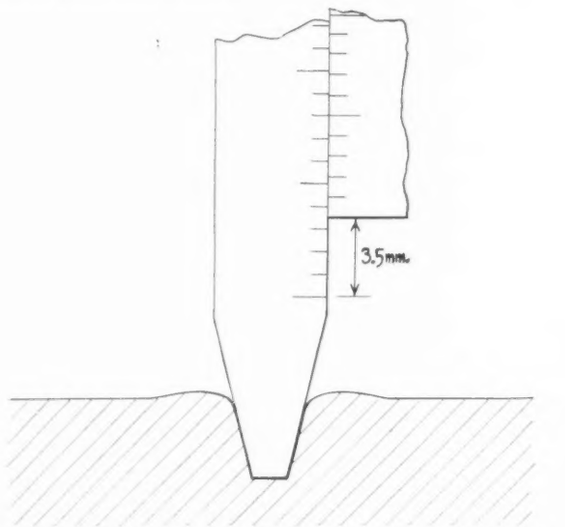


Fig. 92. The point of the penetrator in Calvert and Johnson's hardness tester. The depth of penetration was measured by the scale and vernier.

hardness test in the light of the definition given. Hoyt then states that for brittle materials the ball indentation test should be conducted according to Auerbach's test, which is a slow application of the load until the first appearance of permanent set occurs. In the case of plastic and ductile metals the tests for hardness would be along the lines of the modern ball indenter hardness testers.

Fig. 90 shows the results of some tests made by Hoyt on annealed copper in which the first curve depicts how the diameter of the impression increases as the load on the ball is increased. Meyer had already indicated that such a curve could be represented by the equation

$$P = a\,d^n\ ,$$

the interpretation of which has already been given. Similarly, the second curve shows how the Brinell number varies with the load applied. The Brinell number was calculated from the equation

$$H = \frac{P}{\pi D\left[\frac{D}{2} - \sqrt{\left(\frac{d}{2}\right)^2 - \left(\frac{D}{2}\right)^2}\right]}$$

where D is the diameter of the ball in millimeters and d the diameter of the impression in millimeters produced in the material. The third curve shows the variation of the mean pressure, p_m, as the load is increased. They all go to show that hardness, *per se*, is not expressed by a single factor.

The four articles which have just been briefly reviewed are some of the outstanding papers on a theory of hardness. Thus far, our theories of hardness do not arrive at some constant for this property of hardness as one derives a constant for the various moduli of elasticity. This would be an ideal situation were it possible to do so. The author has already drawn attention to the fact that the hardness of a metal seemed to be definitely related to its yield point, yet the latter cannot, as Hoyt points out, be taken as a measure of hardness. It is the change in these two properties and not the absolute values of these properties which gives us some measure of the hardness.

CALVERT AND JOHNSON'S HARDNESS TESTER

Another early form of an indentation method for hardness testing was the one devised by Calvert and Johnson[9] in 1859. It consists of a heavy metal frame and stand carrying a lever with a high mechanical advantage. This is shown in Fig. 91. As more and more load is applied to the scale pan C, the greater will be the pressure transmitted through a to the penetrator at F. The latter is shown in greater detail in Fig. 92. The penetrator is a truncated cone, 7 mm. long, 5 mm. wide at the base and 1.25 mm. wide at the point. The load added to the scale pan C, in order to penetrate a distance of 3.5 mm. into the substance tested, was taken as a measure of its hardness. This instrument may serve as an example of one of those early steps taken in the development of modern hardness testers.

[9] F. C. Calvert & R. Johnson, On the Hardness of Metals and Alloys. *Philosophical Magazine*, Vol. 17, Series 4, 1859, pages 114-121.

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INSTRUMENTATION FORUM

PROBLEMS — SOLUTIONS — DISCUSSIONS

JANUARY PROBLEM (No. 15)
RADIATION MEASUREMENT

Government Ceramic Engineer desires to run accurate heat balances on small kiln, seeks method of determining heat radiated from shell; states: "There are as many methods of measuring shell temperature as there are experimenters."

$5 PRIZE SOLUTION
By HAROLD T. OLSON
MINNEAPOLIS, MINN.

This problem is essentially identical with one which confronted me a short time ago when it was imperative to determine accurately the energy received by a flat surface variously oriented with respect to a heat source. The equipment which I designed to solve this problem was readily made up from commercially-available products. It worked so satisfactorily that I am passing it on in the belief that its intelligent application will give the information desired.

In principle the device here described is nothing more than a special flow-calorimeter. Inasmuch as the energy received is slight compared to that ordinarily determined by a flow-calorimeter, special precautions must be taken to reduce losses and to increase the sensitivity of the device. This may be done as follows:

(1))The rate of water flow should be kept as low as possible.

(2) The calorimeter should be plated and polished to reduce reradiation as much as possible.

(3) A number of thermocouples in series must be placed in the inlet and outlet tubes to increase the sensitivity to low differences in water temperatures.

(4) The water must be caused to come into intimate contact with the entire body of the calorimeter in order to reduce the time necessary to obtain a stable reading.

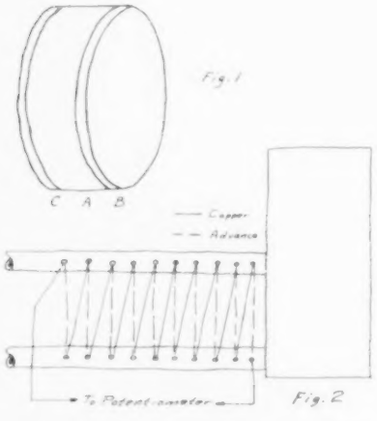

Fig. 1

Fig. 2

These conditions are all met by the apparatus sketched in Fig. 1. *A* is an aluminum block having a large number of holes drilled on centers lying on concentric circles. Slots are cut on the front and back faces between adjacent holes so that the water flows forward through one hole, then across in a slot, back through another hole, across in another slot, etc. The cold water flows first through all of the holes near the outer cylindrical surface, then gradually works its way into the center, passing through each drilled hole only once, and attaining its highest temperature in the center of the block just before flowing out of the calorimeter. *B* is the radiant energy receiver consisting of a flat chemically blackened copper plate which is bolted to the aluminum body. *C* is the aluminum back plate having intake and outlet holes to which are pressed fiber tubes. These tubes have ten holes drilled in their walls and thermocouple are connected as in Fig. 2.

In operation, the water supply is an open pan having a large surface area to reduce the effect of water level variation. The rate of flow is governed by the height of the water surface above the calorimeter. The rate of flow is determined by measuring the time necessary to fill a one-liter flask.

The equation expressing rate of heat absorption in terms of r, the rate of water flow in cc./min., and dT, the increase of the water temperature as it flows through the calorimeter, and A, the area of the face B, is as follows:

$$H = \frac{r \times dT}{A}, \text{cal/in.}^2\text{/min.}$$

The application of this method to any particular kiln depends on such a large number of factors that it is impossible to describe the procedure in further detail. A great deal of the success of the device depends on skill and intuition in choosing appropriate positions at which to take readings.

A suggestion which will aid in obtaining valid results is to determine a surface of constant energy flow about the kiln. Once this surface is determined experimentally, the energy radiated is obviously the product of the surface area by the rate of flow. This may sound unduly involved, but when the degree of symmetry of a kiln is considered, the problem is seen to be not too difficult. In this connection it might be possible to use a thermopile element for a preliminary survey to determine the iso-energy surface and then to use the calorimeter only to obtain the quantitative measure of the energy flow.

Problem No. 17 — Subject Index 8

CHLORINE-CONTENT CONTROL

Large chemical company desires to make its (manual) chlorinators into automatic differential chlorine controllers, requires device for measuring chlorine content of chlorinated water (up to 30 p.p.m.) and actuating the control system. (Note. Problem is the MEASURING part; never mind the relays, etc.)

Five dollars will be paid for every solution (or critical discussion clearly pointing the way to a solution) which is accepted for publication. Address Instrumentation Forum, 1121 Wolfendale St., Pittsburgh, Pa. Type double-space, on one side of paper. Draw diagram in black ink on separate sheet. Mail before April 15. Solutions and discussions accepted will appear in May 1938 issue.

INSTRUMENTS' BOOK SHELF

Direct and Alternating Current Potentiometer Measurements. By D. C. GALL. Chapman & Hall, Ltd., London, 1938. Cloth, $5\frac{1}{2} \times 8\frac{1}{2}$ inches, xiv + 238 pages. Price 15s.

The rapid increase in importance of null or balance methods of electrical measurement is well reflected in this, Vol. IV of a series of British monographs on electrical engineering, and probably the first book in the English language (beyond manufacturers' instruction books) to deal exclusively with the subject of potentiometers. Its treatment of alternating current potentiometers and their uses, occupying over two-thirds of the book, is unquestionably the most complete yet to appear.

The generally accepted potentiometric circuits for direct current measurements are discussed in detail, their relative merits and limitations being clearly pointed out. One short chapter on galvanometers lacks the thoroughness which characterizes the author's treatment of the measuring circuits with which they are used.

The exposition of the alternating current potentiometer exemplifies the work of a master mind; and in full appreciation of the fact that in a-c. measurements there cannot be expected the same precision that may characterize d-c. measurements, the author surmounts many obstacles and shows how there may be attained a degree of accuracy which places that instrument in the category of first-grade laboratory precision apparatus. Some of the results call for the use of circuits and apparatus evolved by the author himself, and some are accomplished by the judicious use of other makes and types of equipment. The versatility of the a-c. potentiometer will surprise many American readers.

Throughout the book the potentiometer is considered as a piece of laboratory and standardization apparatus, no cognizance, other than a passing reference to its use in temperature measurement, being taken of its numerous and rapidly extending applications in industry, or of its amazing possibilities in a self-balancing and recording form.

The author advocates a wider use of the potentiometer in giving students their early instruction in a-c. theory and serious consideration is due his prefatory statements to the effect that "A foundation of clearer understanding can be laid by a practical measurement of the vector values than any voltmeter and ammeter experiment can possibly give. The usual pitfalls of applying vector algebra to a-c. calculations do not arise, because the nature of the qualities involved is understood when they can be measured in vector form and are not just blackboard symbols derived by faith from a theorem taken on trust."

The subject matter of this book is for the most part concisely and logically presented, and the text is clarified by 109 illustrations, including 20 halftones. Though there appear over 100 bibliographical references, a careful scrutiny of

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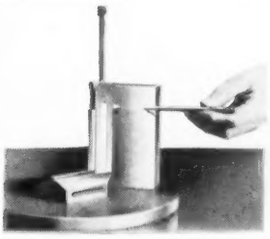

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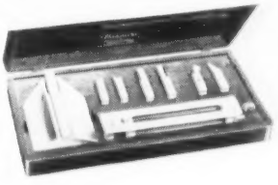

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these shows a certain incompleteness and a seeming lack of familiarity with many pertinent articles which have appeared in the standard technical publications.

Though this volume would not be of primary importance to the engineer entrusted with industrial measurements involving potentiometric methods, it should fill a valuable place in the testing laboratory, particularly of the electrical utility, and as a textbook in the teaching of balance measurements and of a-c. theory to electrical students having at their disposal the equipment necessary for exemplifying the principles set forth.

—PERRY A. BORDEN, *Research and Development Engineer, The Bristol Co., Waterbury, Conn.* (4)-**B**-

How to Make Alignment Charts (1st Edition). By MERRILL G. VAN VOORHIS. McGraw-Hill Book Co., New York, 1937. Cloth, 6 + 9¼ inches, xii × 114 pages. Price $2.50.

In engineering and designing work a large number of calculations are often made involving the same relationship. Such a condition usually necessitates a tedious process of solving the identical equations for different sets of conditions. To save time and to minimize the chance of errors in the calculations, Alignment Charts or Nomographs are often used, particularly in cases where the required accuracy does not exceed 2 or 3 significant figures.

However, the construction of Alignment Charts is usually based on the theory of analytical geometry and differential calculus. This makes their use rather difficult and probably accounts for the reason why so little is known about the actual requirements of their design.

A timely contribution in this field of engineering has been made by Merrill G. Van Voorhis. His book gives in the simplest possible form both the graphical construction of Nomographs as well as the mathematical approach for their design. Great emphasis is placed on how to handle various types of equations, followed by numerous examples of typical industrial applications, which may easily serve as a solution for similar practical applications.

The material is well organized and arranged systematically, beginning with the elementary cases and gradually increasing in complexity of design. Each construction is well explained and the different types coördinated in such a manner that they follow a logical sequence of development, easy to understand without the slightest need of mathematical knowledge. Its 114 pages are full of vital information and will be of great help to anyone in the engineering field or allied branches, who is confronted with the task of choosing the most suitable combination for any particular application which may be arrived at by a graphical chart construction.

—J. O. FELDMARK, *Flow Meter Engineer, The Brown Instrument Co., Philadelphia, Pa.* (1.3)-**B**-

Electrolytic Condensers—Their Properties, Design and Practical Uses. By PHILIP R. COURSEY. Chapman & Hall, Ltd., London, 1937. Cloth, 5½ × 8½ inches, viii + 172 pages. Price 10s 6d.

This volume, probably the first devoted exclusively to this subject, is well written and illustrated mostly with simple diagrammatic figures and actual working curves. It should be of particular interest to students, to actual and potential users of electrolytic condensers, and should find a useful place in technical libraries. Many electrical engineers and radio service engineers desiring information on the general principles involved in electrolytic condenser construction and operation will find sufficient meat in Chapters 8 and 9 to make the book a worth-while addition to their bookshelves. The few specialists in this field might find the book elementary.

Mr. Coursey, who is well-known in the radio art as a condenser specialist, is the author of another book entitled "Electrical Condensers" and of many other articles. Recognized as an authority in this field, being associated since its organization with the oldest and probably the largest condenser manufacturing organization and at present its technical and general director, the author speaks with experience. He is intimately familiar with the practical as well as the technical problems relating to the producing and installation of electrolytic condensers.

The book describes in detail the origin and development of electrolytic condensers, and it is interesting to note that although the industry is really in its infancy as far as commercial production and use is concerned (it being less than 10 years since commercial adoption in the radio field) electrolytic condensers were used experimentally as far back as 1855. In the first chapters the author has concisely connected the heretofore mysterious electrolytic condensers with the well-known static type condenser. Much valuable detailed material is given on the function and importance of the separator, and on the advantage of using two or more thicknesses of separator material. Also, interesting and valuable data are given on the recently popularized condenser of decreased volume utilizing roughened or etched electrodes and thin separators such as paper.

In the past, the great majority of the trouble experienced by users of electrolytic condensers was due to the lack of knowledge of the characteristics of this type of condenser. The author has therefore devoted two chapters to the electrical characteristics and application of electrolytic condensers wherein he describes in detail the effects of temperature, humidity, time, idleness, electrical surges and ripple current on the life of the condenser; and he includes simple circuits and methods for testing these characteristics. He has also illustratively described a large number of electrical circuits employing electrolytic condensers which should serve as a guide to designers and engineers.

The book is a worth-while compilation of information on electrolytic condenser technique in general and on their practical applications.

—WILLIAM DUBILIER, *President and Technical Director, Radio Patents Corp., New York City.* (4.2)-**B**-

INSTRUMERRIMENT

Conducted by Felix Malone, Instrumirthologist

In this department we print each month (mebbe) SERIOUS versions of various subjects treated with too much humor elsewhere in this mag. "Gravity, not levity"—that's our masthead motto. "Solemnity, not jocosity"—that's our sober slogan.

InstruMerrimen Terminology

(Continued)

Serious-minded readers complained of the jollity with which instrument men view their work, and as a stimulus to earnestness they submitted a few technical terms—to which other thoughtful engineers have been adding. We'd like to receive more from equally serious readers.

Strip Chart—A Minsky program.
Standard Cell—Average room in a prison.
Soldering Lug—An electrical development man.
Resistance—What the boss puts up when you want a raise.
Dead Spot—A quiet beer joint.
Damper—Containing more moisture.
Bellows—Cushions for under your head.
Momentum—Keepsake.
File—Small bottle.
Radian—Good-looking.
Thickness Gage—Intelligence test.
Hair Spring—When a rabbit jumps.
Hopper—Swing dancer.
Sine—Accompaniment to petting.
Mu—Cat call.
Blade—Wise guy.
Knife Blade—Indicator of what the boss says to him.
Sal ammoniac cell—A salt and battery*.
Shaper—Corset.
Switch—Chinaman's queue.
Speed indicator—Traffic signal.
Conductivity meters—Those ushering ladies.
Coils—Hair of Goity who woiks on thoity-thoid street.
Cable Testers—Intrigue probers.
Liquid level—Main Street when it rains.
Bellows—College rahs.
Burner—Guy who never pays a touch back.
Contour projector—Silhouette maker.
Feed water—Moisture to wet the whistle.
Pneumatic—A six-shooter.
Shunt—Contraction of shall not.

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